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Bringing well fattened oysters from the artificial culture ponds
OYSTER CULTIVATION IN HOLLAND [See page 164]

Fluorescence—I*

The Phenomenon of "Optimum" Fluorescence in Relation to Molecular Transformation

By Professor Jean Perrin

THE reality of the existence of molecules is no longer to be doubted and every one will admit that it would be highly interesting to obtain direct vision of these minute bodies. Some time ago it occurred to me to enquire whether there might not be some phenomenon by means of which it would be possible to make visible, if not the individual molecules themselves, at least the fluctuations of concentration which must continually exist in the midst of a dilute solution by reason of molecular agitation.

Hoping to find such a phenomenon in fluorescence I examined under the microscope fluorescent solutions, either in very thin sheets in vessels of special form or in thin layers in soap bubbles. I did not succeed in perceiving the separate molecules nor even their fluctuations; however, each of these two investigations enabled me to prove the existence of certain new phenomena. Although this piece of investigation is obviously still incomplete, since it was arrested by the war, it cannot fail to be of value to set forth the results obtained.

Mode of Operation.—A droplet of a fluorescent solution is spread out between the slide and a Zeiss slide cover made of quartz. The thickness of the slide cover was about three microns. An ultra microscopic device (a Zeybmond cardoid) permits an extremely strong light to be thrown upon the preparation, forming in it a very small and very clear image of an electric arc, without allowing any direct ray to penetrate into the microscope focussed upon the preparation. By means of this arrangement the light of the fluorescence alone is perceived without any admixture of the exciting light.

By reason of the extreme thinness and the slight diameter (one-tenth of a millimetre) of the liquid zone illuminated, the thermic conductivity prevents any marked rise in temperature under these conditions in spite of the fierce light of the illumination, even if this illumination is prolonged.¹

The fluorescent subjects examined consisted of all the organic matters possessing visible fluorescence which I was able to procure. The solvent was water, alcohol, xylol or glycerine, the latter being most frequently employed since the high degree of its viscosity and the consequent slowness of diffusion enable us clearly to define and to preserve the modifications produced in the illuminated area of the solution.

The emission of fluorescence involves the destruction of the fluorescent body.—Upon examining a solution of uranin (fluoresceinate of sodium) containing one fifty thousandth part of the chemical in one hundred parts of glycerine, I was astonished to see that the beautiful green color which was at first excited upon the illuminated circle gradually disappeared, leaving in its place at the end of about twenty seconds a black circle, which was very clearly defined by reason of the viscosity of the glycerine. By moving the preparation slightly in such a manner as to illuminate fresh areas, it is easy to obtain under the microscope a brilliantly fluorescent spot in juxtaposition with a dark spot having the contour of the first illumination.

If we cease to illuminate the preparation a progressive regeneration of the altered portions seems to be produced in the course of an hour or two, and one is tempted to believe that the matter destroyed has been re-formed by means of a reversible reaction. In reality, however, what we have here is merely a slow penetration of the uranin present in the non-altered parts of the liquid. In water, which is much more fluid, this diffusion takes place so rapidly that the darkening of the centre of the preparation does not

become total, and an almost permanent condition is attained in a couple of minutes, the edges of the illuminated field remaining soft and more fluorescent than the centre. Furthermore, an exact demonstration that there is no appreciable regeneration, at any rate during the period of several hours, is furnished by the fact that if we succeed in preparing a drop which is narrow enough (one hundred microns) to be entirely illuminated its fluorescence does not reappear when once destroyed.

I do not know what then becomes of the uranin and whether there is, for example (which as we shall see is quite supposable) a polymerization consequent upon the rupture of certain bonds. In order to be in a position to make analyses it would be necessary, for example, to expose large quantities of the solution to sunlight (in a thin layer, since the exciting light is absorbed by the liquid) but the illumination would be much less violent and the duration of the exposure required would apparently have to be quite long.

What I have just described in detail in the case of uranin I found to be true of all the fluorescent organic substances which I investigated. The following table gives a list of the most remarkable of these, together with the color of their fluorescence and the solvent employed:

Fluorescent Bodies	Color of Fluorescence	Solvents
Uranin	Green	Glycerine or Water
Neutral Fluorescein	Green, Blue	"
Phenosafranin	Golden Yellow, then clear Green	"
Morin	Malachite Green	"
Chlorophyll	Blood Red	Alcohol
Eosulin (alkaline)	Sky Blue	Glycerine
Quinine (various salts)	Sky Blue	Water or Glycerine
Methylene Blue	Blood Red	Glycerine
Litmus (alkaline)	Brick Red	Glycerine
Fluorescent Blue	Brilliant Red	Glycerine
Magdala Rose	Brilliant Orange	Alcohol and Glycerine
Anthracene	Violet Indigo	Xylol

The percentage of the fluorescent substance was generally about one ten-thousandth. The duration required to produce a definite darkening of the fluorescent zone varied according to the body, from a few seconds in the case of anthracene or litmus to several minutes for Magdala rose.

Two examples furnished by neutral fluorescein and by phenosafranin prove that the destruction may occur in stages, i. e., the first fluorescent substance disappears giving way to a second substance which is likewise fluorescent and which disappears in its turn. Thus the fluorescence of phenosafranin, which at first is plainly yellow, disappears in a few seconds leaving behind it a spot of tenacious green fluorescence which lasts several minutes before it turns dark. A slight lateral displacement of the preparation readily enables us to juxtapose under the microscope a yellow spot and a green spot, forming a lively contrast in color.

All the fluorogenes here studied contain one or more benzenic nuclei. Reciprocally, it is probable that every molecule having a benzenic nucleus is fluorescent (in the visible or the invisible spectrum). Benzene, and certain phenols notably, have been observed to be fluorescent in the ultra violet area.² It is to be presumed, therefore, that the transformations which accompany these fluorescences belong to the same chemical type. But it has long been known³ that anthracene in solution, when exposed to the light of the sun is transformed into dianthracene. Presumably it is precisely this transformation which is accompanied by fluorescence in the case of anthracene.

Generalizing this result we may suppose that the fluorescences here studied correspond to the dividing off from the benzenic nuclei, which is rendered possible by the rupture, under the influence of the exciting light, of one of the bonds in the case of double bonds.

It is possible that the molecules are fluorescent only at the very instant at which they are destroyed.—Let me say at once that if it be true that an organic body never exhibits fluorescence without being destroyed by the light which makes it shine, then it becomes reasonable to suppose that perhaps it is this destruction which emits the fluorescence. The molecules themselves of those substances which are termed *fluorescent* emit no fluorescence so long as they remain intact.

Contrary to what has been previously supposed, therefore, fluorescence is not due to any permanent

property possessed by certain molecules endowed with the singular power of acting like a sort of machine which absorbs indefinitely light of a certain color, and gives back light of another color. On the contrary, each of these molecules gives forth a flash of light at the moment at which it is chemically transformed.

We shall presently offer new arguments to support this hypothesis.

Temperature and viscosity appear to exert no action;

—The fluorescence of organic bodies does not appear to be much affected by variations of temperature and of viscosity. When excited in the same manner uranin gives forth light in the same way whether in boiling water or cold water, or in glycerine whose viscosity has been so enormously increased that it forms a vitreous mass. I also failed to find any difference when I compared in a manner still more precise the fluorescences exhibited by Magdala rose at the ordinary temperature and in liquid air with percentages varying from one eighth thousandth to one millionth.⁴

I shall shortly return to this matter of indifference to variations of temperature.

Organic coloring matters destroyed by light:—Several of the substances listed in the table given above are well known dyes. As soon as one learns that these are destroyed by light with the emission of fluorescence it seems to me that it is difficult to avoid the temptation to generalize this result with regard to the numerous dyestuffs of which we say they are not "fast" to light. Thus we may suppose that there is fluorescence (either in the visible spectrum or in the invisible spectrum) in the case of all these dyes which are destroyed by prolonged exposure to light. However, it is evidently desirable to obtain more numerous verifications of this fact.

Atomic fluorescences or phosphorescences:—Very interesting questions arise when we compare with the fluorescences here studied the brilliant fluorescences or phosphorescences which can be excited in numerous inorganic compounds, either by light or more particularly by the cathodic rays, the X-rays and the alpha, beta and gamma rays, in all the compounds, apparently, which contain metallic atoms, and which do not possess metallic conductivity, such as the oxides or the glasses. To begin with, while the fluorescences exhibited by organic bodies are connected with the existence of these bodies, i. e., with certain molecular groupings, and may, therefore, be called *molecular fluorescences*, the fluorescences or phosphorescences of the second group may be called *atomic*, for they are characteristic of atoms and, in fact, of metallic atoms (Crookes). For example, the same bands of fluorescence or phosphorescence characterize the neodyme in all its compounds as invariably as do the characteristic lines of its spark spectrum, with this difference, however, that we see that contrary to the intensity of this spectrum, the intensity of the fluorescence or phosphorescence may decrease when the concentration increases.

Furthermore, as soon as we know that organic substances are destroyed while emitting their fluorescence we can hardly help comparing with this phenomenon the progressive "fatigue" which is always displayed by *solids* possessing atomic fluorescence or phosphorescence, under the action of persistent radiation. Such for example, is the well known fatigue exhibited by a glass surface when long exposed to the cathodic rays; in such a case the brilliance of the surface gradually decreases at the same time that it becomes brown or somewhat violet in color (Crookes).

But in this case of atomic fatigue the modification is reversible. The heating of bodies which have been altered upon the surface by the cathodic rays or the alpha rays, or throughout their mass, by the beta or gamma rays, regenerates them; they come back to their original condition, at the same time giving off light in which we find the bands which are characteristic of the metals present. This phenomenon is termed thermo-luminescence.

It is my belief that this thermo-luminescence is not different in nature from the phosphorescence characterized by decreasing luminosity which is emitted after excitation by bodies which have been subjected to active radiations.

⁴Incidentally I took pains to assure myself that there is no relation between the *fluorescences* here studied and the *phosphorescences* observed by Kowalewski in the case of certain organic bodies when they are plunged into liquid air.

*Translated from *Les Annales de Physique* (Paris) for the SCIENTIFIC AMERICAN SUPPLEMENT.

Editorial Note.—Professor Jean Perrin, the Head of the Department of Chemistry in the Faculty of Sciences of the University of Paris, born in 1870 at Lille, is one of the most distinguished living authorities on physical chemistry. The present article presents a new and fascinating theory with regard to the nature of fluorescence in relation to the breaking down and rebuilding of molecules. Professor Perrin was some years ago awarded the Joule prize by the Royal Society of London. Among his works are *The Brownian Movement* and *The Determination of the Absolute Weight of Molecules, Colloids and Electrification by Contact*. Cathodic Rays and X-Rays, etc. He is a collaborator on the *Revue Générale des Sciences*, the *Revue de Més*, and the *Revue Philosophique*.

¹An elevation of a few degrees, but of little importance, would be indicated especially by observation of the Brownian movement of certain suspended particles, and in the case of certain glyceric solutions having a rapidly variable viscosity.

²Stark, *Phys. Zeit.* (Journal of Physics), Vol. VIII, 1907, p. 250.

³Fritzsche, *Journ. für prakt. Chemie* (Journal of Practical Chemistry), Vol. CI, 1866, p. 337.

Theory:—The following qualitative theory takes into account all these facts in their main outlines.*

In the case of atomic fluorescence or phosphorescence it is believed that the active radiations modify the sensitive atoms. Since these atoms are metallic (and therefore readily part with a corpuscle) it is reasonable to suppose (Lenard) that this modification involves the expulsion of a negative corpuscle (or electron). This corpuscle would be arrested at a certain distance, and if the body is solid it would remain imprisoned in a state of forced equilibrium (since this solid does not possess metallic conductivity).

If the expulsion of the corpuscle be accompanied by light, this light will necessarily shine and be extinguished in accord with the exciting light. This would be a *fluorescence* in the precise sense of the word, which implies instantaneousness. We can readily decide whether there is any atomic fluorescence, in fact, by taking measurements in bodies which exhibit long periods of phosphorescence to see whether there is a *discontinuous* diminution in the luminosity at the moment when the excitation ceases.

The reintegration of the corpuscle in the atom which takes place, with more or less facility, according to chance circumstances, occurs at a variable time after the expulsion. The light which is emitted at the moment of these reintegrations must persist, therefore, after the suppression of the exciting light, but will diminish in a manner which can be indicated by exponents. This is a *phosphorescence*. This phosphorescence is greatly facilitated by any cause which diminishes the rigidity of the solid, such as heating (thermo-luminescence). In any case, it is clear that the two stages must be distinguished: for a modification of the atom (with the expulsion of a corpuscle?), certainly implies the absorption of the active radiation and also perhaps, the emission of fluorescence; while a regeneration of the atom implies with equal certainty the emission of light (by phosphorescence).

In the case of molecular fluorescences, and since these fluorescences are not emitted except by bodies which are destroyed, I have been obliged to suppose, as we have seen, that the emission of the fluorescence is due solely to the chemical transformation of the sensitive molecules. In the liquid mediums which I have studied there is no phosphorescence following upon excitation, but such a phosphorescence appears to exist in a solid medium[†] in the case of various coloring matters dissolved in crystals or in gelatine.

Here again two stages are to be distinguished in all cases: the absorption of luminous energy (corresponding, perhaps, to ruptures of valence), and secondly, the emission of light (corresponding to the formation of new molecules).

I shall try to establish new and strong presumptions in favor of this chemical theory of molecular fluorescence by examining a characteristic which it possesses in common with the atomic fluorescences or phosphorescences, the fact, namely, that the emission of light, far from being proportional to the concentration of the active body, is maximum at a certain degree of concentration.

The optimum concentration:—Stokes was the first to show that the fluorescence of organic bodies passes through a maximum when the concentration increases. In the same way Lacoq de Boisbaudran and afterwards G. Urbain, in studying the "cathodic phosphorescence of the rare earths," proved that there always exists a maximum of phosphorescence which corresponds to a rather high degree of dilution of the phosphorogene (corresponding to about one per cent.). It has been proved more exactly (G. Urbain) by increasing the concentration of the phosphorogene, starting at zero, that each band of phosphorescence passes through a maximum, and that the optimum points cannot be attained at the same time by the different bands.[‡] The pure phosphorogene is not phosphorescent.

So far as I know it has not been pointed out, though it is none the less certain, that in the case of a fluorescent solution the optimum concentration depends upon the thickness of the liquid layer under examination.[§] I am able to state that the optimum concentration for any thickness whatever remains less than twenty per cent., i. e. less than a semi-normal molecular concentration (by reason of the high molecular weights of fluorescent bodies). This is the same degree that we

find in the cathodic phosphorescences (two per cent. of the neodyme makes a concentration in an oxide which is about one-third normal).

This maximum of fluorescence (or of phosphorescence), which has heretofore remained an enigma, can be readily interpreted if we consider the fluorescence per unit of mass for each degree of concentration and at each point.

* * * * *

Fluorescent power in very dilute solutions:—I have assumed that the fluorescent power decreases starting from a finite value at the same time that the concentration increases starting from zero. In actual fact this result was obtained in research work conducted under my direction by the late M. Lépine.[¶]

Taking into account, in those degrees of concentration where this was necessary, the absorption of the exciting light in the first layers traversed, M. Lépine established the fact by means of precise photometric measurements (for uranin, fluorescent blue, rhodamine) that in concentrations comprised between one billionth and one two hundred thousandth "the fluorescence of a given volume is exactly proportional to the concentration." This may be stated in another form as follows:

Beyond a certain degree of dilution the fluorescence of a given mass remains constant. The fluorescent power, therefore, has a well defined limit.

It results likewise from the experiment of Lépine that beyond a concentration of 1 one-hundred thousandth the fluorescence of a given mass begins to decrease appreciably, just as I had predicted that it would do. In slightly different language, and since the emission of fluorescence indicates the destruction of sensitive molecules, we may say:

Beyond a certain degree of dilution the chances of destruction of a fluorogene molecule remain constant. These chances of destruction diminish when the molecules come closer together as the solution becomes more concentrated.

We may say that the fluorogene molecules reciprocally protect each other, and that the nearer they are to each other the better they do this; this protection is at first very insignificant, i. e., where the degree of dilution is very great, and it becomes more and more efficacious as the concentration proceeds until almost complete immunity is obtained.

The fluorescence of a concentrated solution which is exposed to the light grows first brighter then dimmer until it is extinguished:—I have investigated the phenomenon of optimum concentration by means of the ultra microscope in layers of varying thickness from that of three microns down to about the tenth of a micron for certain observations. As was to be foreseen the phenomenon reappeared. For example, a thirty per cent. solution of esculin, or a twenty-five per cent. solution of uranin, exhibits almost no fluorescence in these thin layers. At the same time I observed certain new features which are curious enough, although quite easy to interpret.

In the case of strong concentrations, those greater than twenty per cent. for instance, the fluorescence is very slight. But if we allow the preparation to remain exposed to the exciting light we see this fluorescence begin to grow brighter, at first very slowly, and then rapidly, until it attains an insupportable degree of brilliance, after which it begins to grow dim and finally dies away.

The theory which we have just set forth readily enables us to comprehend what occurs: so long as the concentration is great the fluorescence is feeble, though it exists and the substance undergoes a slow destruction. At the same time its concentration, of course, is decreasing, which causes an increase in the fluorescent power, and the total fluorescence becomes greater and greater until the optimum degree of concentration is attained, after which this total fluorescence necessarily decreases until the fluorescent substance has been completely destroyed. It is clear that even under ordinary conditions of thickness and of illumination it would be possible to note analogous phenomena provided the observations were continued over a period of several years.

It is probable that molecules are fluorescent only at the instant when they undergo chemical transformation:

—Upon observing the phenomenon which I have just described more attentively we perceive that it furnishes new and strong reasons for considering molecular fluorescence as the manifestation of a chemical transformation.

[¶]Lépine (killed by the enemy in 1915), Experimental Study of the Fluorescence of Solutions (Paris, diplôme d'Etudes, No. 171, 1914). This remarkable diploma by means of its precision leads to various interesting conclusions besides the result here indicated.

tion and not as a permanent physical property of molecules which have remained intact.

Droplets or extremely thin streaks^{||} of a fourteen per cent. glycerine solution of uranin were placed upon the surface of a quartz slide by dragging across it a microscopic glass thread which had been dipped in the solution; the microscope was then focussed upon this slide. Under the influence of the exciting light the brilliance of the drops increased until it reached its maximum value corresponding to the optimum concentration after the lapse of about one minute. Moreover, when the ten per cent. solution of uranin was made use of, only a few seconds were required for the attainment of this maximum luminosity. We are obliged to believe, therefore, that in about fifty seconds a fourteen per cent. solution is reduced to a content of ten per cent. If the reduction continued at this rate of progress without being accelerated it would require about a quarter of an hour to reach the degree of concentration at which, in these thicknesses, the fluorescence would have practically disappeared. But the fact is that this appearance occurred after the lapse of only one minute, starting from the instant of maximum luminosity. It is evident, therefore, that the percentage of destruction by the light is much higher when the concentration is very slight, or what comes to the same thing, the more dilute a given mass the more rapidly it is destroyed.

But it is equally true that the slighter the concentration the greater the fluorescence *per unit of mass*. In fact, as I demonstrated above, it is because the fluorescence per unit of mass decreases when the concentration increases that we are enabled to observe a maximum of fluorescence in a layer having a definite thickness. For a given mass of the fluorescent body, therefore, the emission of fluorescence, and the rapidity with which the said body disappears, vary in the same direction.^{||} The emission of fluorescence and the concentration for a given mass, on the contrary, vary in the opposite direction.

Thus it appears to be most probable that, as I stated above, fluorescence does not at all indicate molecules which are still intact, but the disappearance of these molecules. *It is only at the moment when they disappear in order to give birth to molecules of a new kind that the molecules are revealed by fluorescence.*

We cannot fail to make an immediate extension of this idea to the atomic fluorescences or phosphorescences, in which as we have seen there likewise exists an optimum concentration. For example, it cannot be the intact atoms of the neodyme which shine but only those which are suddenly either altered or regenerated. I must insist also upon the profound difference which is thus demonstrated to exist between fluorescence and a physical property which characterizes molecules which have remained intact; like that property, for example, to which we attribute the "color" of bodies.

For example, the color which is allowed to pass by a solution of bromine in chloroform is due to the molecules of bromine which compose that layer. The absorption is perceptibly proportional to the degree of concentration for a thin layer having a definite thickness. There is nothing here, therefore, which recalls the phenomenon of the optimum: we know perfectly well that the color of a solution of bromine of a given thickness does not pass through a maximum for a certain degree of concentration beyond which it will again become transparent by the addition of fresh quantities of bromine.

On the contrary, the centres of emission of the fluorescence which is given forth by uranin, when the latter is excited by light, are not molecules of uranin; and if our eyes were sufficiently powerful to enable us to see these luminous centres individually, we would not perceive the intact molecules of uranin, but only those which happen to be in the process of being destroyed. In the same manner (merely by way of comparison, of course) it is not the atoms of radium which are the centres of emission of the radio-active rays, but the points of instantaneous explosion where an atom of radium disappears while sending forth an atom of niton and an atom of helium. As for the intact molecules of uranin, they are capable of possessing, and they do possess in fact, a color properly so-called, from which there results an absorption which increases in proportion to the degree of concentration, but without passing through an optimum point.

[TO BE CONCLUDED.]

^{||}And proportionally to each other, I assume, without yet having a sufficient number of quantitative proofs, i. e., the necessary photometric measurements.

^{||}With respect to the nature of the bonds thus broken I have already suggested that in the case of the fluorogenes here studied it is perhaps a matter of double bonds between atoms of carbon. But other groups of fluorescences must exist. I will very shortly explain how they possibly embrace the totality of chemical reactions.

*The phenomena of tribo-luminescence, which are probably connected with the piezo- or pyro-electric properties, as well as the phosphorescences, which really consist according to their spectra of electric discharges or effluvia passing through very thin gaseous layers, are not here taken into consideration as they belong to an entirely different type.

[†]Schmidt, *Wied. Ann.* Vol. LVII, 1896.

[‡]Urbain, *Comptes Rendus*, Vol. CXLVII, 1908, p. 1286.

[§]In the case of the cathodic phosphorescences the thickness of the layer is defined by the depth at which the cathodic corpuscles are buried.



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Oyster pits at Jerseke, Holland

Oyster Cultivation in Holland

ALTHOUGH the oysters grown in European waters do not compare favorably with the American varieties either in quality or flavor, still they are a highly appreciated delicacy, and considerable attention is given to their cultivation. In this industry, however, Holland is the most systematic in its operations and employs more elaborate methods than any other country in the world.

The numerous sounds that indent the coast of Holland, particularly in the region of the mouth of the River Scheldt, afford excellent facilities for the propagation of the oyster, and enable the country to conduct the most successful oyster industry in Europe. Public dredging is not permitted, as the result of that system was the threatened exhaustion of the fisheries, and the beds have been carefully surveyed, and specific tracts are leased to individuals and companies who are thus enabled to conduct the propagation of the oyster in a systematic manner that insures the best results from the territory available. Many growers lease several tracts in different localities, and adapted to different purposes, which facilitates the various operations, as the oysters can be shifted from one place to another, according to the season and the stage of development.

In the most advanced method of culture collectors, consisting of square Dutch roofing tiles, mounted on pegs, are set on edge in rows in shallow water, and on these the spat, or fry, find a ready resting place as they float in with the tide. During the summer these collectors are shifted about, as occasion requires, to prevent them from being covered by silt, and to remove the enemies of the oysters, such as crabs and starfish; and on the approach of winter these tiles are transferred from the outside banks to enclosed ponds, where the water is kept at a sufficient depth to guard against freezing. In the following spring the young oysters are carefully removed from the tiles, which were coated with lime so that the oysters can be easily detached without injury, and placed in ponds, or shallow areas, where they are left to grow and fatten. This requires from three to four years before they arrive at a marketable size.

The accompanying illustrations show how extensive and elaborate is the arrangement of these propagating ponds, which are designed so that the water may be changed as desired, and its depth regulated as may be necessary.

A few of the oystermen plant shells on the banks, as is done in many places in this country, but the largest and most successful propagators are equipped with their own tanks and ponds, located in convenient shallow bays, in which they carry on the culture in the manner outlined above.

The Role of the Catalyst*

THE catalyst is assuming an importance no less in medicine than in industries. Chemists long ago found out the peculiar action of a third party in promoting chemical interaction. The classic example is that of the preparation of oxygen gas from chlorate of potassium. The fused mass of the salt, with heat still applied to it, yields its oxygen reluctantly, but at that point it is dangerous to introduce a trace of manganese dioxide since at once the evolution of oxygen becomes explosive though the manganese remains unchanged. An earlier example of catalysis was the Döbereiner lamp, in which spongy platinum was the catalyst effecting the union of a mixture of hydrogen and oxygen at

such a speed that ignition was the result. The most remarkable catalyst of all is water, without which, it has been shown, combustion or oxidation is impossible. Similarly the louse is a catalyst in respect of man and trench fever. Catalysts, briefly, are promoters of chemical action for reasons not yet fully explained. They may function equally in the relatively cold or under conditions of high temperature. The remarkable behavior of catalysts in the human body at its normal temperature illustrates the importance of their action in promoting healthy nutrition, which after all means the complete chemical assimilation of food substances.

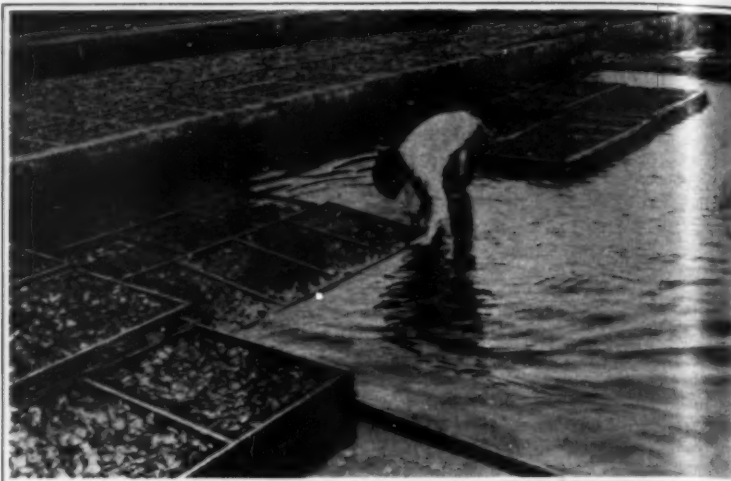
We have much yet to learn as to the nature of the action of the accessory factors in food—for convenience called vitamins—which serve as antineuritic and an-



Cleaning oysters

discorbic agents. It is conceivable that in the chemical sense they act as catalysts—that is, as a third party, rendering the potentialities of food available for the maintenance and growth of the organism. It is known, at all events, that they occur in quite minute proportions, in spite of which they prove to be essential to growth. When we consider the very remarkable results produced in great industrial processes by the agency of the merest trace of a third party, the catalyst, our views are strengthened as to the importance of a certain factor present in however minute quantity. There is good reason for suggesting that the vitamins are catalysts just as are the enzymes, whose action in many respects resembles that of inorganic catalysts, particularly in the colloidal state. Dr. G. G. Henderson, in a recent valuable treatise on Catalysis in Industrial Chemistry,¹ says that the term "catalysis" is now generally used to designate those chemical changes of which the progress is modified by the presence of a foreign substance, and he further points out that it has for long been known that the velocity of many chemical reactions which take place very slowly if the reacting substances alone are present in the system is greatly increased by the addition of certain substances, which have the same composition after the change has been completed as at the beginning, and which therefore appear to influence the course of the reaction without taking any definite stoichiometric part. This

¹Catalysis in Industrial Chemistry, by G. G. Henderson, M.A., D.Sc., LL.D., F.R.S. Longmans, Green & Co., London, 1919, pp. 202, price 9s.



Preparing young oysters for wintering in pits

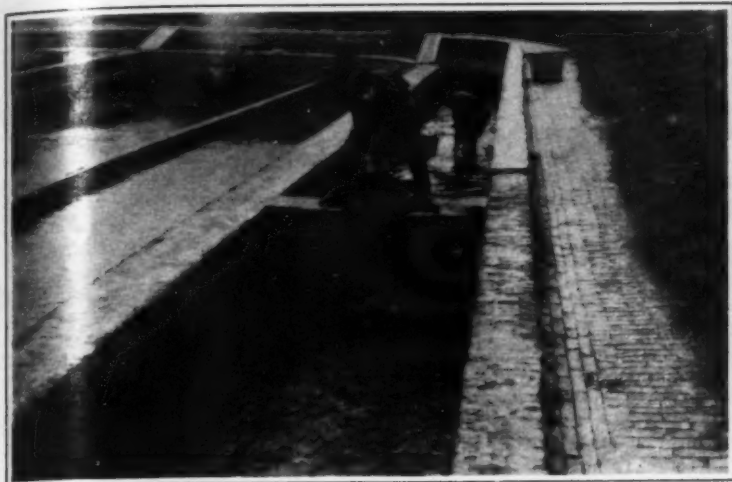
definition would appear to include all accessory food factors as catalysts, having no direct nutritive value themselves, but serving as promoters of a nutrient consumption.

The application of catalysts in industrial operations is growing very rapidly in importance, and the behavior in many respects of the catalysts employed shows a curious parallel to well-known physiological phenomena. Traces of arsenic, mercury, sulphur, hydrocyanic acid, "poison" in so many cases the catalysts' activities, and there are also negative catalysts which inhibit the action of positive catalysts not by "poisoning" them but by neutralising their potentialities as acid does an alkali. Sir Edward Thorpe, writing in his introduction to the excellent "Monographs on Industrial Chemistry" now being issued, says an obscure phenomenon like catalysis is found to be capable of widespread application in manufacturing operations of the most diverse character. The phenomenon may be obscure, but its applications are suggesting great possibilities in arts and industries which are bound to have an important bearing on the commercial prosperity of this country. The catalyst, in short, promises to open a way to important economic productions, as witness the hardening of liquid fats for food purposes, the production of fertilisers from the air, and the output of many valuable commercial products. The advances made and the vista opened up by the study of catalytic action, though confined largely to industrial processes, should persuade biologists, as well as biological chemists—we see no dividing line between these two schools of workers—to accept a cue which, followed, may lead to results in the study of life processes of immeasurable importance. The part played by conceivably a catalyst in human nutrition may, when thoroughly investigated, enable us to adopt a regimen which will secure for certain patients a dietary in which the supply of accessory factors is well represented. It is a matter of history that industrial developments have been shown to give a helping hand to medicine—the coal-gas industry with its output of antiseptics, synthetics, and colors, the brewing and wine industries which formed the basis of Pasteur's successful researches are cases in point. The prominent place which the catalyst is rapidly taking in industrial advances will shed a light on the chemistry of the human mechanism, its liabilities, and the factors which count in its healthy maintenance.

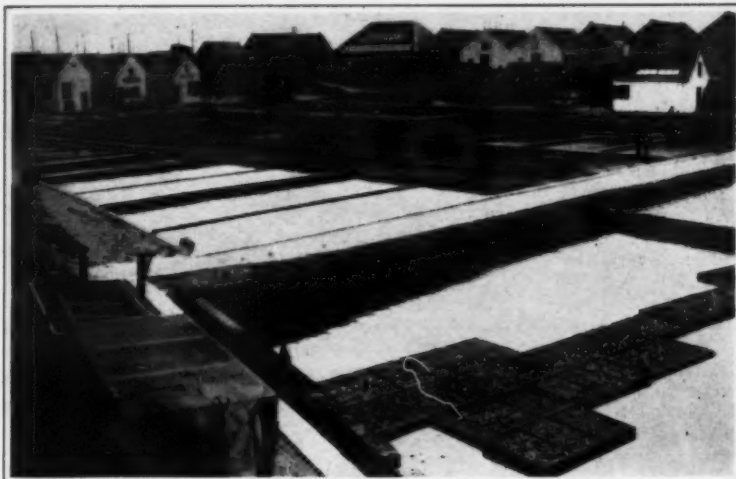
Prejudicial Effects of Treatment with Formalin Upon the Germination of Seeds

It has been customary to treat seed corn with formaldehyde solutions to get rid of bunt in oats and rust in wheat, and this treatment has been observed to influence germination. Culture and germination experiments extending over two years showed that the immersion of seed in a solution containing 0.1 per 1,000 of formaldehyde for a quarter of an hour retarded the onset of germination and also the total time of germination, although the number of plants obtained was about the same as from untreated seed. When artificially damaged seeds were submitted to treatment, they appeared to undergo no greater injury than sound seeds. Some of the injurious effects were due to the presence of impurities, such as methyl alcohol, in the solutions used, which are customarily prepared from formalin, and it was proved that it would be better to employ pure solutions prepared from paraformaldehyde. The use of formalin to protect seeds against mildew is not to be recommended, unless a pure solution of formaldehyde is used or part of the formalin is replaced by another fungicide.—Note in *J. Soc. Chem. Ind.* on an article by L. Kiessling, in *J. Landw.*

*The Lancet.



Changing the water in the pits



General view of a large oyster plant

Science in Cacao Production

A. W. Knapp

THERE is a great field for the application of physical and chemical knowledge to the production of the raw materials of the tropics. In one or two instances notable advances have been made, thus the direct production of a white sugar (as now practised in Java) at the tropical factory will have far-reaching effects, but with many tropical products the methods practised are as ancient as they are haphazard. Like all methods founded on long experience they suit the environment and the temperament of the people who use them, so that the work of the scientist in introducing improvements requires intimate knowledge of the conditions if his suggestions are to be adopted. The various Departments of Agriculture are doing splendid pioneer work, but the full harvest of their sowing will not be reaped until the number of tropically-educated agriculturists has been increased by the founding of three or four agricultural colleges and research laboratories in equatorial regions.

(a) *World production.*—To illustrate the above generalisation I propose to take the production of cacao (the seed or bean from which cocoa is prepared). At the present time the average yield per tree is surprisingly small, being about $1\frac{1}{2}$ to 2 lb. a year, and the total world production is about 290,000 tons a year. By scientific agriculture, taking a conservative estimate, the average yield per tree could be raised to 6 lb. and the total production to over a million tons a year.

(b) *Harvesting the crop.*—The cacao tree is about the size of an apple tree and the pods grow on its trunk and stems. The tree will not bear climbing, and the pods are cut from the tree by knives on the ends of poles: a difficult operation. Considerable ingenuity has been exercised to produce a gatherer which will sever the pod-stems and yet be "fool-proof," but the ideal method of collecting has yet to be found.

(c) *Extracting the beans.*—The pods have to be cut and the juicy beans removed. This is generally done with a cutlass. What is needed is a knife which will cut the husk of the pod without injuring the beans within. The placenta (the part of a plant to which the seeds are attached) contains a fair percentage of pectin, of which no use is made.

(d) *Conveying cacao to the fermentation house.*—Mechanical transport is very rare indeed, only in one or two places is use made of trucks running on Decauville rails. It is, however, in use in San Thomé, where a single estate will produce 2,000 tons a year.

(e) *Fermenting.*—The seeds or beans are covered with a juicy pulp and would rot if they were not dried. The best way to remove the pulp is to allow it to ferment; this occurs naturally on exposure to air, as with grape-juice. The effects of fermentation are various and, with good fortune, all advantageous—the bean becomes more easy to dry, and on drying becomes crisp; it develops a richer color, and on roasting, a finer aroma and flavor. Fermented cacao always fetches a higher price than unfermented cacao from the same place, but fermentation is by no means universally practised. Hence one finds on the market considerable quantities of cacao which contain mouldy beans, for unfermented cacao readily goes mouldy; this is a serious loss to the world. Fermentation is not carried on anywhere in a scientific manner, everywhere the cacao is at the mercy of the chance organisms in the air. The quality of the cacao produced varies, and the quality is reflected in the prices obtained; thus the Food Controller has fixed the price of British West African cacao at 65s. a cwt.,

Grenada at 85s. a cwt., and Ceylon at 100s. a cwt. The quality of any cacao is the result of the botanic variety or "breed," plus the treatment it receives in preparation for the market. Now Grenada and Ceylon cacaos are obviously different in "breed," so that Grenada cannot hope by fermentation, however scientific, to get the Ceylon bean. The line of improvement for Grenada is to try the planting and rearing of the more delicate Ceylon type of cacao. With the cacao from Grenada and British West Africa the case is otherwise. The British West African bean is of a very similar type to that grown in Grenada and is slightly superior



Both men and women work at the oyster pits

because it is larger and contains less shell (about 12 per cent. as against 15 per cent.). Grenada beans are very carefully prepared (if not scientifically yet with great art) and give practically 100 per cent. perfect beans. This is the explanation of the higher price given for Grenada cacao, although at the present time this difference is magnified by exceptional conditions.

No entirely satisfactory theory of the changes in cacao due to fermentation has yet been established. It is known that the sugary pulp outside the beans ferments in a similar way to other fruit pulp, save that for yeast fermentation the temperature rises unusually high (in three days to 47° C.); and also that there are parallel and more important changes in the interior of the bean. Flickendey, Loew, Nicholls, Preyer, Schulte im Hofe, and Sack, have made useful contributions to the subject, and recently Brill has determined the actual ferments present. He finds casease, protease, oxidase, raffinase, invertase, diastase, and an emulsin. But there is still a vast amount of work to be done before the chemist will be in a position to obtain the more desirable aromas and flavors. Having found the necessary conditions scientifically trained overseers will be required to carry them out, and for this they

will need to have under their direction arrangements for fermentation designed on correct principles and allowing some degree of control. Possibly also enterprising firms will build competing types of plant, in portable sections, easily erected. In these, mechanical mixing will replace the present laborious method of turning the beans by hand. They will doubtless be fitted with suitable devices for catching the liquid which flows away from the beans during fermentation. In choosing a suitable material the makers will have to remember that the beans and pulp contain tannic and acetic acids. As the present overseers generally have no knowledge of chemistry, they do not understand how the appearance of the cacao may be spoiled by the iron nails used in constructing the fermentation boxes. One sometimes sees corrugated iron roofing corroded by acetic acid vapor, or a cement floor eaten into by the acid juice. This leads to the question of the use of the juice which runs away from the beans during conveyance and during fermentation. At present all this runs to waste, and it cannot be less than eight million gallons a year. This juice or "sweatings" contains about 15 per cent. of solids, about half of which consists of sugars. If the fermentation of the cacao were centralized in the various districts, and conducted on a large scale under a chemist's control, the sugars could be obtained, or an alcoholic liquid or a vinegar could easily be prepared. This acid liquid might also be used for the coagulation of rubber latex. Sir George Watt, in 1913, patented a portable machine for extracting the beans. It cuts off the base of the pod, squeezes out the beans, and includes an arrangement for collecting and preserving the juice which is produced by this operation. This machine has apparently never been used. Machines which are used for drying the beans have, however, met with a better fate.

(f) *Drying.*—This is the only point in cacao production which has received much attention from the engineer. Whether the cacao has been fermented or not, it has to be dried to prevent it going mouldy. The common practice is to spread it on platforms or mats and dry in the sun. In a few places, where sun-drying is difficult, drying machines are slowly coming into vogue. Many engineering firms make drying plants of one sort or another, drying by hot air, *in vacuo*, etc., and doubtless the general principles of drying are well understood, but to make a really satisfactory drying machine one must have knowledge of the chemical and physical nature of the raw product. Too often the makers conclude that a machine which will dry one product is suitable for all others. The great opportunities of the future should encourage further research, for now that transport is so costly the value of drying all tropical products is enhanced. In the drying of cacao, apart from loss of acetic acid, more than mere loss of moisture occurs. It has been pointed out by several observers, notably by Schulte im Hofe, that during sun-drying the changes due to fermentation continue, particularly the change due to an oxidase, *i. e.*, the oxidation of a tannin, which results in the removal of the astringent taste and the development of a brown color. With drying machines the conditions are often unfavorable to this action. This is one of the reasons why at present manufacturers of cocoa slightly prefer sun-dried cacao.

Criticism could be made of the various subsidiary processes (washing, claying, polishing, etc.) to which the beans are subjected in different countries, but sufficient has been said to give an idea of the wide field for research and of the opportunities for the application of known facts.—*Jour. Soc. of Chem. Industry.*

Ocean Temperatures in Long-Range Forecasting*

By Charles F. Brooks

"Besides trying to predict the extremely variable state of the fickle atmosphere one should give more attention to the conservative element of meteorology, viz., the surface sheet of the ocean where changes may be observed months before their effect on our weather becomes manifest. [For example] a sensible departure from the average value of the vast amount of stored heat carried through the [Florida] Straits might have profound effects on the weather of the following months on the European and North American Continents."

These two sentences by Dr. Hans Pettersen¹ led me to compare monthly departures of air temperature at stations in the eastern United States with those in the Gulf Stream. Encouraged by the results, I extended the investigation backward into the make-up of the Gulf Stream and Antilles Current, forward into the movement of the Gulf Stream Drift, and the effects of the Labrador Current, and upward into the influence of water temperatures on the overlying air. A report on the preliminary results just a year ago led to the active co-operation of the Weather Bureau in mapping more data, and later the Signal Corps offered additional help.

Let me outline the general basis which seems to make worth while the contemplated extensive investigation of ocean temperatures in long-range forecasting. If it is possible (1) to forecast the distribution of surface water temperature a few weeks in advance, it may prove possible (2) to forecast the general paths which will be followed by cyclones and anticyclones; and then (3), from the winds which will result, to make long-range forecasts of the general weather to be expected in any period. Let us consider each of these points more in detail.

1. How do water surface temperature departures originate and move?

Insolation and radiation are the most important factors in the general heating and cooling of the ocean surface. The temperature of the air is of little consequence in the heating and still less in the cooling of the ocean surface, for the specific heat of water per unit volume is about 3,300 times that of air under ordinary conditions.

Departures of the temperatures of the sea surface from the normal are almost wholly the result of variations in wind direction and velocity. Holland-Hansen and Nansen have shown in their recent book² that in middle latitudes of the Atlantic the wind direction is largely responsible for the occurrence of plus and minus temperature departures. Following a winter month with the prevailing wind north of the normal over any region, the water temperatures are almost invariably below normal, while a month with prevailing winds south of normal is followed in the next by water temperatures above normal. The air temperature, of course, shows similar, though greater and more immediate, departures. The coldness or warmth of the water is probably dependent more on transportation of water from colder or warmer latitudes than on the cooling or warming by the wind which is driving it. At any rate the evaluation of each factor is of little consequence for both act to produce the same result.

The effect of changes in wind velocity is most noticeable in the Tropics, where changes in direction are of little or no effect. When the trade winds are unusually strong for a period, the warm layer of surface water is driven forward and concentrated in the Equatorial Current, where it forms a plus departure in temperature. The place of this warm surface sheet is taken by cooler subsurface water, making a minus departure. Under the influence of the wind the area of plus departure followed by that of minus moves slowly westward. Using Hepworth's data,³ I found that most months of unusually strong northeast trade winds in the eastern Atlantic are followed in 4 to 6 months by plus departures in the temperature of the surface water passing through the Straits of Florida, and in 8 to 11 months by minus departures. The southeast trade in the eastern Atlantic, acting through the south Equatorial Current, part of which feeds the Gulf Stream, produces a similar plus and then minus departure in the Straits of Florida, 6 to 9 and 10 to 14 months, respectively, after the month of unusually strong south-east trade.

*A paper presented at the Baltimore meeting of the Association of American Geographers.

¹Meteorological Aspects of Oceanography, M. W. R., June, 1916, 44:338-341, 2 figs.

²Temperatur-Schwankungen des Nordatlantischen Ozeans und in der Atmosphäre, Christiania, 1917. See author's abstract, M. W. R., April, 1918, 46:177-178.

³M. C. W. Hepworth, The Trade Winds of the Atlantic Ocean. Metl. Office, London, No. 208, 1910.

What happens to these waters of varying temperature as they debouch into the Atlantic? The strength of the Gulf Stream carries them forward to the region south of Nantucket within a month; but their identities are not lost for several months more in the case of water markedly warmer or colder than usual. In fact, in spite of the obliterating effects of shifting winds of varying strengths, many of the water temperature departures observed in the Gulf Stream, Antilles Current, or Labrador Current are discernible many months later on the coast of Europe, especially when the water has made most of the transit in the quieter months of the year. From the Straits of Florida to the edge of the European continental shelf at about latitude 50 degrees, the temperature departures take 8 to 10 months. The effects of changes in the Labrador Current on the Grand Banks take equally long. But the departures in the Antilles Current east of the Bahamas take but 5 to 7 months to cross the Atlantic.

Think of the travels of an important plus temperature departure, for instance between latitudes 5° and 45° in the North Atlantic. Originating, perhaps, in the eastern Atlantic during a month of strong trades (the strength of which may still farther back depend on the water temperature distribution) and proceeding across the Atlantic, many of these departures in the course of 4 to 6 months pass through the Straits of Florida; and in 8 to 10 months more they may be felt off the west coast of Europe. Thence some of the important departures may complete the circuit and appear in the Straits of Florida 15 months still later. In spite of the great complexities introduced by changing winds, it is evident that there are possibilities of forecasting the distribution of ocean surface temperatures.

2. How do these ocean temperatures control atmospheric pressure and winds?

It is a matter of common knowledge that in autumn and winter in middle and high latitudes bodies of water are marked by low pressure areas because of their warmth, and in spring and summer by high pressure areas in the regions where the water is appreciably colder than the land. Many investigators have shown that this is true for particular months, and that peculiar water temperature distributions are marked by corresponding pressure features. As weather forecasters well know, the individual cyclones tend to follow paths across the warmer regions and to be intensified where there are sharp contrasts in temperature; and the anticyclones tend similarly to follow paths across the colder regions and to maintain the highest pressures over the coldest parts.

J. Petersen has described in detail how the Iceland Low moves back and forth between southern Greenland and the Norwegian Sea in response to the changing distribution of water temperatures induced by its own winds.⁴ When the Iceland Low is west, the strong southwest winds in the eastern Atlantic bring warm air and drive warm water far northeastward; while northerly winds along the Greenland coast bring cold water southward. The rise of temperature in the east and the fall in the west favor a fall of pressure in the east and a rise in the west. Consequently, the center of lowest pressure moves eastward. But when the Iceland Low is centered in the east, the northwest winds west of the British Isles drive cold water toward the coast of Europe; while farther north, warm water is being driven westward. The resulting cooling in the east and warming in the west favor a return of the center of the Iceland Low to its first position; and the cycle begins anew.

The general circulation of the atmosphere favors high pressures in latitudes 25° to 40° and low pressures between latitudes 50° and 65°. The particular locations of the permanent and semipermanent centers of high pressure are likely to be the coldest spots in the low-latitude belt; while the centers of general low pressure will probably be in the warmest spots of the high-latitude belt. The intensities of these centers of action seem to be functions both of the strength of the general circulation and of the temperature contrasts in approximately the same latitudes.

3. What weather occurs with winds which accompany any pressure type?

A body of unusually warm water coming through the Straits of Florida, as in January, 1916, on spreading over the western Atlantic south and east of New England makes a very favorable region for cyclones. In consequence, we experience such unusual cold and snowy north and northeast winds as made the snowy winter of 1915-16 famous in the Middle and North At-

lantic States.⁵ In February, March and April, of 1916, many cyclones approaching the Atlantic coast passed eastward, out to sea; became intense over the warm water, and then weakened over the cooler water beyond.⁶ Thus, we have the paradox that an unusually warm Gulf Stream favors cold weather in the eastern United States, while a "cool" Gulf Stream favors warm weather.⁷

For the different pressure types the weather is well known, both in Europe and in this country; so, if the probable position and strength of the center of action can be forecast, the details will follow easily.

It is evident that general answers of a favorable kind, even though not firmly established, are already at hand for the three questions, and that much work has already been done. It remains to co-ordinate these results and to add considerably to the data already mapped. While we might be able to compute the subsequent pressure distribution from the present surface temperatures and winds, the problem is too complicated to be solved quickly in this way. We need to attack this problem in the same way that the daily forecasting difficulties were met; make a thousand maps, classify them according to types, and forecast empirically if the dynamic basis is not clear. While this is simple to say, the use of ocean temperatures in long-range forecasting will be a tremendously complicated proceeding. It seems probable that certain types of pressure distribution, as averaged for 10-30 day periods, can be associated with certain types of surface water temperature distribution. In making a forecast of the pressure distribution for month after next, for instance, it might be necessary to go through the following procedure: (1) Forecast how the water temperatures will change during the next 10 days under the action of the present winds; (2) forecast a slight rearrangement of the tracks of cyclones and anticyclones in accordance with this changed water surface temperature distribution; (3) apply the winds of this forecast pressure distribution to the movement of the water for the next 10 days; (4) go through the round a few times more; (5) as some kind of a check compare the results with the sequences on previous occasions following similar original pressure and water-temperature associations. Longer range, more general forecasts might be made by watching closely the Gulf Stream in the Straits of Florida and the Japan Current off Formosa.

POSSIBLE APPLICATIONS TO THE NORTH PACIFIC REGION.

[Conclusion of a paper on "Possibilities of Long-Range Seasonal Weather Forecasts Based on Ocean Temperatures: With Especial Reference to an Investigation of the North Pacific," read at the conference on this subject during the semicentennial celebration of the founding of the University of California, Mar. 18-21, 1918.]

The first steps for an investigation of the North Pacific Ocean, in particular, would be to procure plenty of current atmospheric pressure and temperature data. The area is so vast that if we are to have a satisfactory picture of the weather and water conditions of the Pacific Ocean, all ships and all lighthouses operating in this region should be equipped to take water temperature and atmospheric pressure observations. These observations should be made available within a month of the time they are taken, if possible at some international establishment where they can be used immediately for the construction of maps. At this bureau, there could be a corps constantly engaged in mapping the data, getting averages for 10-day and 30-day maps, and making the computations necessary for the construction of forecast maps.

On the research side a profitable beginning has been made by T. Okada⁸ and others in their investigations of weather correlations in the Pacific region. In closing, I wish to call attention to the desirability of applying to the Pacific certain correlations which have been worked out for the Atlantic Ocean. P. H. Gallé is now making winter temperature forecasts for central and western Europe on the basis of the strength of the trade winds during the preceding May to October.⁹ February to March and March to April tem-

⁴Cf. New England Snowfall, M. W. R., June, 1917, 46:271-285, and Geogr. Rev., Mar., 1917, 3:222-240.

⁵See the discussion of the marine data for November, 1917, on chart IX and p. 538 of this issue of the Review for a somewhat similar occurrence of a southwestward displacement of the Iceland Low over an area of unusually high water temperatures.

⁶Cf. The "Old-Fashioned" Winter of 1917-18, Geogr. Rev., May, 1918, 5:405-414.

⁷Journ. Meteorological Soc. of Japan, December, 1915, May and June, 1917; also M. W. R., 1916, 44:17-21, 238-240; 1917, 45:299-300, 535-538.

⁸On the relation between the summer changes of the North Atlantic trade winds and winter temperature in Europe." Proc. Amsterdam Roy. Acad. of Sci., vol. 18, 1916, pp. 1435-1448.

⁹"Unperiodische Temperaturschwankungen im Golf Strom und deren Beziehung zu der Luftdruckverteilung." Am. d. Hydrog. u. Mar. Met. 1910, 38:397-417, 2 pls.

peratures for the same region are indicated fairly well by the pressure gradient between Copenhagen and Styksholm during the preceding September to January, inclusive, or by the December water or air temperatures on the middle Norwegian coast.²⁹ The summer temperatures in all the Baltic region are indicated by the winter temperatures of the water about Iceland; and the general character of the April to September rainfall at Berlin, at least, is indicated by the Thorshavn rainfall of the preceding January to March.³¹

Expressed in terms of the Pacific region, these correlations would be as follows: The departures of the strength of the trade wind from the normal at Hawaii during the period May to October (perhaps earlier) may indicate a departure of the same sign in British Columbia during the months December to February following. The pressure gradient between Seattle and Dutch Harbor, September to January, inclusive, or the December air or water temperatures on the coast of southern Alaska when compared with the corresponding values of the year before may give a direct indication of the coming February to March and March to April temperatures relative to those of the same periods of the year before, which will probably have a chance of verification greater than 80 per cent. in the region west of the continental divide and north of the forty-second parallel. Finally, the winter water temperatures at Dutch Harbor, and the January to March rainfall on the south Alaskan coast may give for the following summer a direct indication of the temperature and rainfall, respectively, for British Columbia and Washington.

These are, necessarily, rather generalized weather indications; and in themselves may not be of much use. They are, however, convenient as starting points for the many years of investigation which lie ahead of us to determine what the meteorological conditions of the North Pacific are, and how they may be used for making seasonal forecasts for the bordering lands, and with the help of Atlantic conditions, perhaps for the whole of North America.

The Medicolegal Aspects of Radium-Therapy*

By Joseph B. Bissel, M.D., New York

ALL remedial agents used in the art of healing are subject to various forms of application which may result through proper use in a relief of the condition treated or by improper application may bring about disastrous results to the patient and to the practitioner alike. Damages accruing from faulty instructions of a mechanical engineer may quickly cause a financial loss enormous in proportions. It is rare that we find mistakes evidenced in the chemical formulas evolved by the operators laying out work in our great commercial organizations. In that branch of science which has for its purpose the study and treatment of the human body we unfortunately find all too frequent evidence to show that mistakes, errors in judgment, and lack of technical knowledge play sad havoc in their result. It is therefore most fitting that we bring to your attention the true status of affairs that may relate to the application of radium in medicine and surgery.

The Local or External Application of Radium.—Possibly no subject in medicine or surgery has so widely interested the lay public as has radium. This interest is stimulated by belief that there may lie in this substance that which will ultimately bring us a cure to the most horrible of all diseases, cancer. That we can reasonably look forward with an ever-increasing degree of hope in this agent is made clear by the remarkable success that is being attained in the treatment of malignant conditions purely superficial in type. The clinical improvements and apparent cures in those cancerous masses to which radium can be directly applied run well over 80 per cent. and are increasing in proportion with our knowledge of better technique and an understanding of accurate dosage. It will further interest you to know that those deep-seated growths located in the interior of the body, in its cavities, etc., held as incurable, are giving increasing promise as we find means of applying this active element directly to the mass. It would not be proper in making such statements as this to lay the entire claim for this beneficial influence on radium alone. We must clearly understand that radium is but one of the means at the command of the surgeon and we must rely upon his ability to know when to discontinue his work with the knife and take up another instrument whose application is far more humane and yet deeper and more effective in

its power. The space allotted to me will not permit me to go into the various forms of technique used in the treatment of the types of cancer that come to the surgeon for remedy.

Internal Use of Radium.—More than ten years of clinical achievement at the great hospital centers of Europe where radium has been used internally give us certain definite knowledge as to its value for the treatment of many diseases dependent on early degeneration of the kidneys, heart and blood-vessels associated with imperfect elimination of the body's waste products, causing self-poisoning of the patient. Such diseases as nephritis, arteriosclerosis, and various forms of arthritis or rheumatism, so called, which we commonly know to incapacitate so many men in early years are now held as curable or controllable to a large degree by radium-therapy, properly administered. Innumerable are the channels of hopeful therapy that follow the administration of the emanation of radium in cases evidencing faulty cell activity and circulatory changes.

Let this suffice as a general classification for the more common indications for the use of radium in its various forms and from such a theme, let us make our deductions as to the medicolegal aspects resultant from the use of radium. When radium is applied locally we look forward to certain anatomical and physical changes. If the type of the mass and the character of its cell structure are thoroughly understood we will hope to see its activity of growth checked, the tumor being decreased in size, either without any apparent breaking down of its structure or by degeneration of the mass and a general sloughing off of its substance. Under successful treatments the classic result shows a disappearance of the growth entirely. Where such results are not to be obtained due to the uncontrollable activity of the cancer cell we may be justified in answering that as yet there is little to hope for in the way of promised cure, but we may apply radium in such a case, because of our definite knowledge that radium will largely control the hemorrhage, reduce the odor, hold in check the symptoms of pain, modify to a large extent the active congestion present, and restore to the patient hope. These briefly are the possibilities for local application.

The medicolegal aspects of such treatment will depend on two general classifications, the ability of the surgeon in diagnosis and statements relating thereto and the quality and quantity of the radium element at his command and his ability to estimate proper dosage. It is most natural to assume that the practitioner would hesitate to specialize in the treatment of malignant diseases either with the knife, caustic pastes, or radium unless he had derived extensive knowledge as a clinician and was backed up with suitable laboratory facilities to insure correct diagnosis. It is the duty of the operator for his own protection and for the benefit of the patient to know as far as possible the exact type of the growth to be attacked. Certain types of cancer present tremendous activity in growth and require a large amount of radium coupled with long periods of application. Other structures exhibiting cell growth of lower vitality can easily be treated with smaller dosage. Then again there are certain locations in the human body, such as in the region of the mouth and throat, wherein we are possibly not justified in making any operative procedures even for microscopic examination. In this region active growth most grave in its type frequently follows surgical interference.

So far as radium itself is concerned there are four possible channels of danger from its applications; namely, from a dosage applied in the regions like the bladder, stomach and esophagus resulting in a burn following which might come penetration, infection and death; secondly, from the possibility of activating the growth of cancer cells by an insufficient dosage; thirdly, the possibility of danger from the action of radium directly on the walls of large blood-vessels lying in the immediate vicinity of the mass treated, causing a rupture of the blood-vessel and fatal hemorrhage following the effects of a burn; fourthly, the possibility of affecting the ovary when radium is applied in regions in close proximity to it. Radium burns in general have no terrors. A troublesome burn at times will occur where an extremely large dose of radium has been given and screened with most careful technique. There are certain cases, such as those of extreme malignant type met in the throat, that we treat with the heaviest dosage possible with the full expectation that we will get a deep severe burn. We would not be giving sufficient dosage did we not get such a manifestation. The one hope in a desperate case of cancer of the tongue is to give the fan the heaviest dose of radium possible and screen it in such a manner as to permit him to secure administer the heaviest dose of radium possible and is therefore told that a burn will probably develop and

every such radium patient should be similarly warned. There is absolutely no danger in a radium burn other than penetration. The surface heals slowly, sometimes taking weeks and months to recover. At times following heavy ray treatment we find a resultant heavy layer of fibrous tissue which may remain permanently.

Undoubtedly insufficient dosage of radium at times tends to increase the growth and activity of cancer structures. This cannot be held, however, in condemnation of radium because in all probability at the stage reached any interference, whether it be a knife, caustics, or radium, would possibly exert the same influence. However, it is extremely important that a proper dosage be administered. The serious consequences coming from the application of radium without every precaution in the neighborhood of large blood-vessels would undoubtedly be a reasonable subject for medicolegal consideration. Properly administered, radium has been used in this country in local application with doses varying from two milligrams to one thousand milligrams without effecting burns which would have any medicolegal aspects. Of course, such treatments were carried on with perfect technique. In working in the vicinity of such organs as the eye, one must naturally protect, by sufficient screenage, that portion not affected by the cancer. Nature has considerably protected the radium worker by giving resistance to normal tissue of many times that of the cancerous structure and therefore it is possible for us to apply very large dosage, destructive in type to the cancer mass and not do serious damage to adjoining tissue. Radium should in no wise be considered a caustic or tissue-destroying agent. Its destructive properties come from the action of radium directly on the blood-vessels of the structure. There may possibly be a further action on the intercellular substances; the nutrition being cut off from the mass causes its death and degeneration. There are but few opportunities for a scientific worker with radium to make mistakes and we trust that so powerful and energetic an agent as radium will not be placed in hands improperly schooled. The dangers of the gamma ray from α -ray treatment are of common knowledge to everyone, and we find some people confuse the gamma ray of that apparatus with radium. They are analogous but not at all similar, and where the α -ray burn at times develops into cancer the radium burn is inert and is itself used to cure the α -ray malignancy.

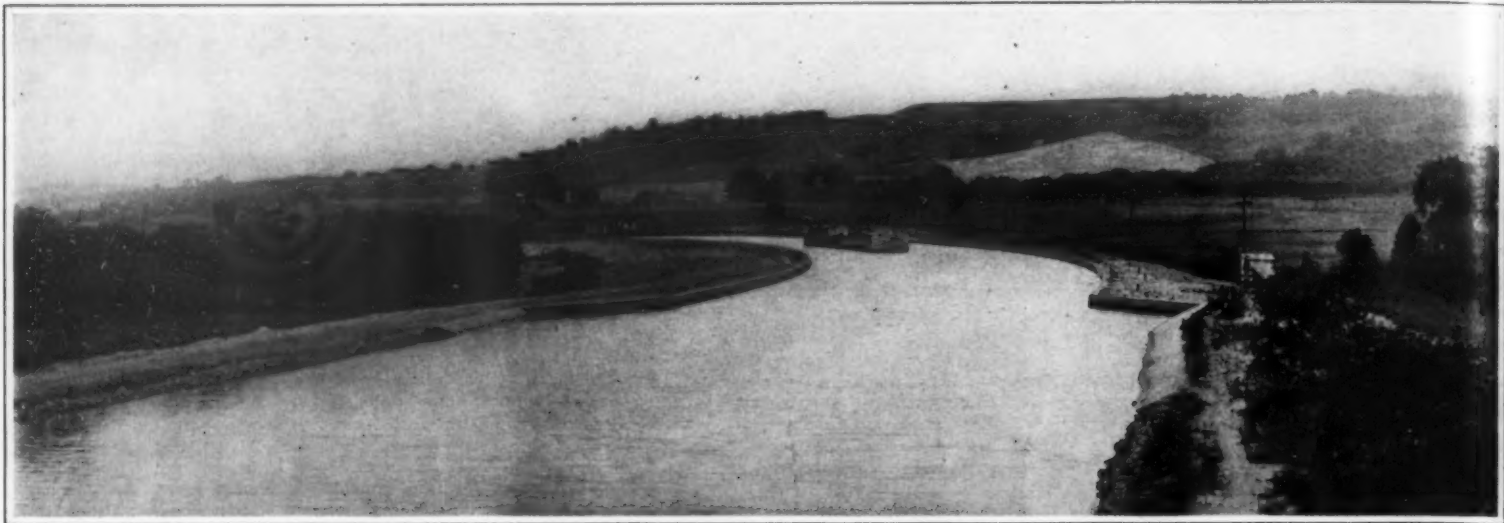
Just a word relating to the internal administration of radium. This branch of radium-therapy is of equal importance with the local application and its responsibilities are often greater. With radium it is possible at times to restore to usefulness the man who in the prime of life is crippled to invalidism by a rheumatic affection.

Radium may serve to control certain of the dangers of high blood pressure commonly met in the arteriosclerosis case or markedly influence the metabolism and elimination in cardiac and nephritic patients. If such results are forthcoming from the use of radium emanation then it is truly a most important remedy. With this in view, let us ask ourselves the question, What is the danger or medicolegal aspect as relates to the internal administration of radium? In answer to this I would say that experience has shown that radium is accepted as harmoniously in the body as is sunlight by the withering plant. Doses have been administered to use a common unit of from 500 M. U. to 27,000,000 M. U. of emanation without danger of harmful influence. Radium injected into the blood can easily be traced in its elimination, and while it is active for many weeks, its complete disappearance from the body is assured. Definite measurements governing elimination are at hand. There seems to be no evidence that would point to any danger from radium when used internally. One point of warning, however, must be offered. Unqualified practitioners, poor diagnosticians, and men lacking clinical experience could, of course, make mistakes and cause damage even with radium. It is to be regretted that there are still men in the practice of medicine who are not qualified by an experience or ability to be treating human kind. If we have an extremely high blood pressure of the compensating type, such pressure possibly should not be reduced. It is accomplishing its purpose. The only reduction that should be attempted in such a case would be that secured by a combined treatment of both cause and effect. That radium does exert a remarkable influence in the treatment of antritis, gout, and diseases of faulty elimination in general must be acknowledged, and the time will soon be at hand when the practitioner who does not use all methods of treatment at hand before failing in his arteriosclerosis cases, in administering aid to his desperate rheumatic patients, and who does not relieve those diseases of the heart and kidneys by advanced measures of therapy when indicated, will be guilty of malpractice, and so charged.

*From the Medical Record.

²⁹W. Mehnardus "Ueber einige meteorologische Beziehungen zwischen dem Nordatlantischen Ozean und Europa im Winterhalbjahr." Met. Zeits., 1898, 2 pl., pp. 55-104.

³¹H. H. Hildebrandson "Quelques recherches sur les centres d'action de l'atmosphère." V. (last). Kongl. Svenska. Vetenskapsakad. Handl. 51, No. 8, 1914, 16 pp., 13 pl.



A typical view on the New York Barge Canal

The Canal in the Problem of Transportation

What New York Has Done in Its Modern Development

By G. P. Gleason

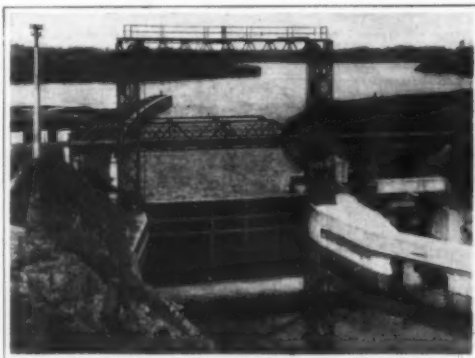
THE many exigencies which have arisen since our declaration of war have made it imperative that we overlook no elements which will help us emerge from the struggle victorious. How well this truth is appreciated can be seen by reviewing the great strides which have been made and the results obtained during the period we have been engaged in the world's struggle for freedom. The peculiar conditions attending the conflict, however, have placed the problem of transportation and supply at the head of our list of absolute essentials and, perhaps, there is no question so far-reaching and complex as that of moving our troops, munitions and supplies to the battle front. That phase of the situation doing with the movement of our easterly boundary is, in itself, a gigantic one but is, by no means, more difficult of solution than the one dealing with the movement of produce and the avoidance of congestion on the routes connecting our productive centres and manufacturing districts with the Atlantic Seaboard.

The whole problem, however, has one phase which stands out pre-eminently and that is the truth that the constant and unvarying direction our war freight must take is from west to east. There can be no deviation from this line if our troops and munitions are to move the shortest distance and follow the natural lines. Inasmuch as victory depends upon the rapid transportation of all freight and the speedy dispatch of our troops, any variation from the west to east course, except for some fully compensating reason could be classed as an error of the greatest magnitude if not, indeed, as a transportation crime.

But true, as these things are, they do not constitute all of the angles of the situation as we faced it when we cast our weight into the balance against autocracy. We had already experienced a congestion of freight unparalleled in the history of the nation. The railroads had been forced to place embargoes on many items, with the result, that many manufacturing plants were forced to slacken their work and there was much confusion among our industries. This the Federal authorities sought to overcome as the first step in the solution of the problem and, to bring this about, the government took over the operation of the rail lines, thereby uniting them in one massive system for war purposes. But, standing alone, the railroads cannot handle all of the traffic and, in order to obtain the best results and render the most efficient service, there must be a thorough co-ordination between all lines of communication. This means that every available waterway, each suitable highway and the trolley systems must be utilized.

Owing to this the New York State Barge Canal which was started in 1905 and, by a fortunate coincidence, opened to navigation on all its branches last May, assumed a value undreamed of by its original projectors. This new waterway is the last word in canal building and is one

of the foremost examples of engineering skill in the world. It, however, lies on the direct west to east line and serves as the only thoroughly up-to-date water route connecting the Great Lakes with the Atlantic Ocean. This is not, as many believe, one channel running from the Hudson River to Lake Erie, but is a complete waterway system within itself and consists of four different channels covering various productive parts of the State. These branches are: The Erie, extending across the State from the Hudson to Lake Erie; the Champlain running northward, along the



A steel guard gate at the junction of the canal with the Mohawk River

easterly boundary of the State from Troy to Whitehall on Lake Champlain; the Oswego, branching from the Erie at Syracuse and connecting that branch with Lake Ontario and the Cayuga-Seneca, leaving the main channel west of the Oswego junction and joining the two large lakes from which it derives its name.

All of these canals have the same general dimensions, the minimum depth being 12 feet and the width varying from 75 feet at the bottom of earth sections of the "land line" or artificial channel to a minimum of 200 feet in the beds of the canalized rivers and lakes which constitute the larger portion of the system.



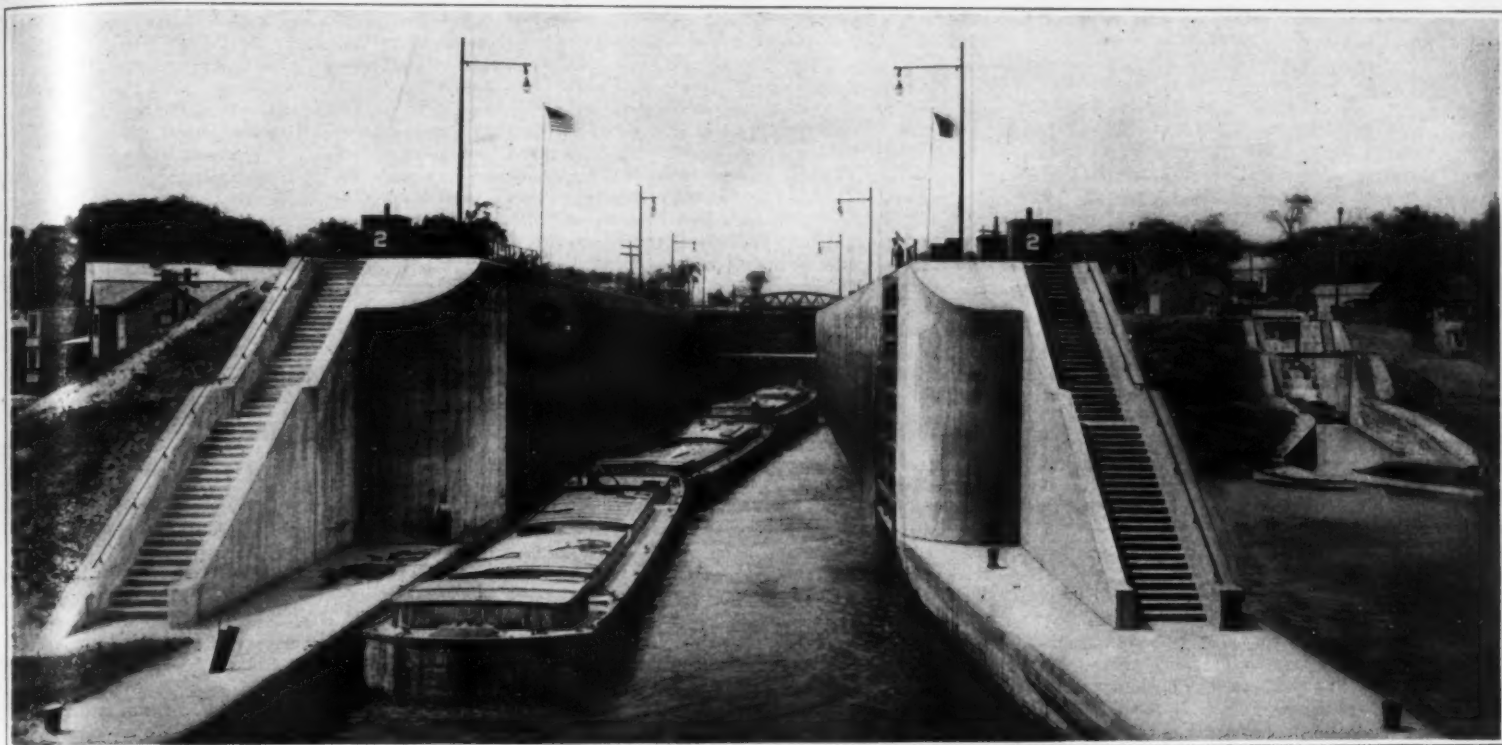
A siphon lock at Oswego, the largest lock of its kind ever constructed, and the first in this country

From an engineering viewpoint the State's waterway contains many interesting and unique features. Foremost among them and, perhaps of the greatest interest to the average person, are the massive movable dams crossing the Mohawk River between Little Falls and Schenectady and aiding in the canalization of that stream. These dams closely resemble steel bridges in appearance, each having piers and abutments, as well as superstructures by hinges, the upper parts of which are connected. Approaches, however, are lacking and from the downstream side of each are suspended a series of steel frames, the upper parts of which are connected to the superstructures by hinges, while the bottoms rest in a concrete sill extending across the bed of the river. Heavy steel gates, in tiers of two or three, are placed on these frames and so constructed that they may be raised or lowered by means of electric winches, running on the bridge floor of the dam, the bottoms of the gates forming the lower tier, resting on the concrete sill while the upper series form the crest of the dam.

This type of structure was adopted after a most searching study of conditions existing in the Mohawk Valley. The river, which has been canalized by dredging and the construction of dams, as well as locks, is subject to severe floods. Had fixed dams been provided this excess water could not be passed freely with the result that each spring the river would overflow its banks, causing much damage to the surrounding country. The movable dam serves to remove this menace as, by raising the gates and frames, the channel is left unrestricted during the flood period; whereas in the summer months the gates are lowered and the structure assumes its full purpose as a dam. Furthermore, by raising one or more of the gates as desired those charged with the maintenance of navigation can regulate the depth of water in the channel above the dam and practically eliminate all currents in the stream.

Among the dams of the fixed type there are a number worthy of particular notice. These are located at Crescent and Vischer's Ferry on the Erie branch and at Seneca Falls on the Cayuga-Seneca Canal. The former structures across the Mohawk River, each being about 2,000 feet in length, while the structure at Seneca Falls is notable for its height which is 75 feet. Other dams of the same type have been provided with Talntor gates which fill the regulating notches and may be opened or closed as desired, to permit the discharge or storage of water.

The largest dams on the Canal System are those at the two storage reservoirs of Delta and Hinckley. In general the rivers and streams provide the channel with sufficient water to meet all navigation requirements. East of Rome, however, the Erie is a canalization of the Mohawk River which makes a gradual



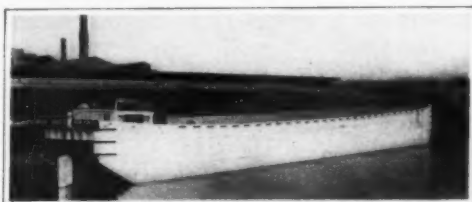
Locks of the old and new Erie Canal, showing the vast scale of the modern undertaking

descent toward the Hudson. In order to assure enough water to maintain the 12-foot depth and to provide for all lockages, it was found necessary to establish two-storage reservoirs in the Adirondack watershed. One of these is located a few miles north of Rome and is situated where the village of Delta once stood. This crosses the upper Mohawk River and is 1,000 feet in length, 100 feet high and contains 90,000 cubic yards of masonry while the reservoir has an area at crest level of $4\frac{1}{2}$ square miles. The capacity of this is 2,750,000,000 cubic feet of water. The Hinckley Dam is located near the village by that name and is mainly an earthen structure crossing West Canada Creek. This dam is 3,700 feet long and 82 feet high. It contains 110,020 cubic yards of masonry and 611,200 cubic yards of earth. The reservoir has a crest area of nearly 5 square miles and a capacity of 3,445,000,000 cubic feet of water.

Next to the dams in point of interest are the new locks on the system. Each of these structures is built of concrete and is operated and lighted by electricity, the inside dimensions of each being 30 by 44 feet. The height of lift varies from a few feet to a maximum of $40\frac{1}{2}$ feet, the highest one on the system being located at Little Falls. The five massive structures constituting the Waterford series, at the eastern terminus of the waterway, have a combined lift of 160 feet or double that of all those at Panama from sea level to summit. One of the most unique locks in the world is at Oswego. This utilizes the siphon principle in its operation and is the largest structure of this type in the world and the first to be constructed in this country.

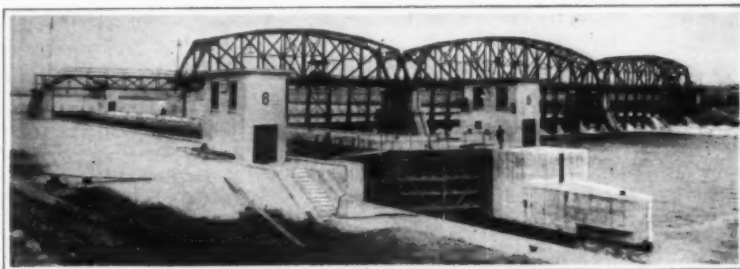
The great importance of the terminal has been illustrated by the decline of traffic on all waterways where such provision for loading, unloading and storing freight has been lacking. On the Mississippi River there are no terminals, save a few scattered dockwalls that are owned and operated by the railroads. As a result there is very little traffic on the river, as the railways control the rates and have made it impossible for the independent shippers to receive the lowered rate that should go with water transportation. The practical disappearance of traffic on the old canals in New York State has also been laid to this same neglect and lack of foresight on the part of those interested in the waterways. On the Continent, however, the terminals are owned and operated by either the canal lines or municipalities and the result is that the water lines and not the railroads control the rates.

All of the locks are provided with steel gates which are opened and closed by electricity, generated in hydro-electric stations or gasoline-electric power plants. The water is admitted to the chamber by means of culverts



The first 1000-ton barge built for use on the new canal

running through the side walls and connected with a series of port holes that have been located at the bottom of the wall. The flow of water through these ports is governed by vertical slide valves which are operated by electricity, the position of the valves being shown by a system of electric signal lights in the "controller cabinet" on the lock wall.



Movable dam and lock on the Mohawk River

There are many other structures of note on the State's waterway including guard gates, suspended from skeleton steel towers, spillways of different types to protect the nearby country from floods due to an overflow of the embankment, lighthouses to aid in night navigation on the lake sections, not to mention some 300 highway and railroad bridges and numerous minor



The famous curved dam at Oswego

structures. The work on the channel necessitated an excavation of upwards of 300,000,000 yards of earth and rock while approximately 3,000,000 yards of concrete has been placed. The total expenditure was upwards of \$150,000,000, this sum including \$19,800,000 that has been set aside for the construction and equipment of 55 barge canal terminals. These latter aids to commerce have been deemed absolutely essential by all transportation authorities and the terminal system of New York State will be one of the most complete ever established in this country.

The New York State Terminal System will be most complete in every respect. Dockwalls have already been constructed in all important shipping points. Aside from this the terminal consists of a pavement, while mechanical devices for loading and unloading the barges, with freight sheds and warehouses for the storage of the goods will be provided. Furthermore, most of the important terminals will have spurs connecting them with the railroad lines so that produce may be shipped inland and off the canal at joint rail and water rate.

This new waterway will carry upwards of 10,000,000 tons of freight per year. This will mean that thousands of freight cars now operating on lines running parallel to the system and carrying produce which the canals are better adapted to move, will be released for other service. The water route is admittedly more efficient and economical for the transportation of heavy, bulky commodities such as iron ore, coal, lumber, etc., than are the rail lines. The Barge Canal, however, will not be limited to this but thanks to its terminal system, is in a position whereby it can offer a service that is parallel, though not identical to that rendered by the competitive railroads.

The many advantages to be obtained by a full use of the water route are very apparent. First, the lowered rates, and canal rates on all but government operated lines are about one-half those asked by competitive railroads, is bound to attract shippers and benefit the business man and consumer alike. Second the speed maintained by a modern barge is an item which stands in favor of the canal. As to this it need only be said that three seasons' operation of finished portions of the Barge Canal have demonstrated that a suitably constructed barge can move at the rate of 140 miles a day; whereas the average loaded freight train makes but 40 miles in a like period. Third, responsible barge lines, maintaining a regular schedule on the channels and operating suitable barges will contribute largely toward the re-establishment of confidence in the waterways. Fourth, an up-to-date terminal system affording all proper facilities to aid in the transfer of cargoes and the storage of goods will give the canal a type of service unequalled on any water-

way in the world and will enable the shippers to maintain their own rates.

As a link in our line of communication the new system has many things to recommend it to popular consideration. Foremost among these is the fact that it is the only waterway connecting the productive centres of the Middle West with the Atlantic Ocean. Just what this means to commerce can be better grasped when it is considered that in one year Lake Erie floated 137,229,258 tons of freight while 1,439 vessels were operating on the Great Lakes. Furthermore, the records available will show that out of all the freight moved on Lake Erie but a very small portion of it moved through the Welland Canal into Lake Ontario. In fact this latter lake floated but 336,930 tons while Lake Huron carried 7,400,757 tons, showing that by far most of the freight on the Great Lakes is centered on Lake Erie and that a large part of it was moved by rail to and from this body of water.

The new channel has already demonstrated its worth in the present emergency. It has furnished a route whereby numerous submarine destroyers, mine sweepers and other light warcraft have been moved from the shipyards on the Great Lakes to the Atlantic. The Federal authorities by taking over the operation of the canal have shown that they have appreciated its value and, in fact, it has already served to carry much war freight and munitions to our transports and embarkation ports. All told the new channel is a mighty link in our national transportation system and, as time goes on, it will continue to contribute its share in a greater portion toward the firm establishment of an economic and efficient service that will work a direct benefit upon our industries and foreign shipping.

On the Lubricating and Other Properties of Thin Oily Films

By Lord Rayleigh, O.M., F.R.S.

THE experiments about to be described were undertaken to examine more particularly a fact well known in most households. A cup of tea, standing in a dry saucer, is apt to slip about in an awkward manner, for which a remedy is found in the introduction of a few drops of water, or tea, wetting the parts in contact. The explanation is not obvious, and I remember discussing the question with Kelvin many years ago, but with little progress.

It is true that a drop of liquid between two curved surfaces draws them together and so may increase the friction. If d be the distance between the plates at the edge of the film, T the capillary tension, and α the angle of contact, the whole force is (see, for example, Maxwell on "Capillarity," Collected Papers, II., 571):—

$$\frac{2AT \cos \alpha}{d} + BT \sin \alpha.$$

A being the area of the film between the plates and B its circumference. If the fluid wets the plate, $\alpha=0$ and we have simply $2AT/d$. For example, if $d=6 \times 10^{-8}$ cm., equal to a wave length of ordinary light, and T (as for water) be 74 dynes per cm., the force per sq. cm. is 25×105 dynes, a suction of $2\frac{1}{2}$ atmospheres. For the present purpose we may express d in terms of the radius of curvature (ρ) of one of the surfaces, the other being supposed flat, and the distance (x) from the centre to the edge of the film. In two dimensions $d=x^2/2\rho$, and A (per unit of length in the third dimension) $=2x$, so that the force per unit of length is $8\rho T/x$, inversely as x . On the other hand in the more important case of symmetry round the common normal, $A=\pi x^2$, and the whole force is $4\pi\rho T$, independent of x , but increasing with the radius of curvature. For example, if $T=74$ dynes per cm., and $\rho=100$ cm., the force is 925 dynes, or the weight of about 1 gm. The radius of curvature (ρ) might, of course, be much greater. There are circumstances where this force is of importance; but, as we shall see presently, it does not avail to explain the effects now under consideration.

My first experiments were very simple ones, with a slab of thick plate glass and a small glass bottle weighing about 4 oz. The diameter of the bottle is $4\frac{1}{2}$ cm., and the bottom is concave, bounded by a rim which is not ground, but makes a fairly good fit with the plate. The slab is placed upon a slope, and the subject of observation is the slipping of the bottle upon it. If we begin with surfaces washed and well rubbed with an ordinary cloth, or gone over with a recently wiped hand, we find that at a suitable inclination the conditions are uniform, the bottle starting slowly, and moving freely from every position. If now we breathe upon the slab, maintained in a fixed position, or upon the bottle, or upon both, we find that the bottle sticks, and requires very sensible forces to make it move down. A like result ensues when the

contacts are thoroughly wetted with water instead of being merely damped. When, after damping with the breath, evaporation removes the moisture, almost complete recovery of the original slipperiness recurs.

In the slippery condition the surfaces, though apparently clean, are undoubtedly coated with an invisible greasy layer. If, after a thorough washing and rubbing under the tap, the surfaces are dried by evaporation after shaking off as much of the water as possible, they are found to be sticky as compared with the condition after wiping. A better experiment was made with substitution of a strip of thinner glass about 5 cm. wide for the thick slab. This was heated strongly by an alcohol flame, preferably with use of a blowpipe. At a certain angle of inclination the bottle was held everywhere, but on going over the surface with the fingers, not purposely greased, free movement ensued. As might have been expected, the clean surface is sticky as compared with one slightly greased; the difficulty so far is to explain the effect of moisture upon a surface already slightly greased. It was not surprising that the effect of alcohol was similar to that of water.

At this stage it was important to make sure that the stickiness due to water was not connected with the minuteness of the quantity in operation. Accordingly, a glass plate was mounted at a suitable angle in a dish filled with water. Upon this fully drowned surface the bottle stuck, the inclination being such that on the slightest greasing the motion became free. In another experiment the water in the dish was replaced by paraffin oil. There was decided stickiness as compared with surfaces slightly greasy.

The better to guard against the ordinary operation of surface tension, the weight of the bottle was increased by inclusion of mercury until it reached 20 oz., but without material modification of the effects observed. The moisture of the breath, or drowning in water whether clean or soapy, developed the same stickiness as before.

The next series of experiments was a little more elaborate. In order to obtain measures more readily, and to facilitate drowning of the contacts, the slab was used in the horizontal position, and the movable piece was pulled by a thread which started horizontally, and passing over a pulley carried a small pan into which weights could be placed. The pan itself weighed 1 oz. (28 grms.). Another change was the substitution for the bottle of a small carriage standing on glass legs terminating in 3 feet of hemispherical form and 5 mm. in diameter. The whole weight of the carriage, as loaded, was $7\frac{1}{2}$ oz. The object of the substitution was to eliminate any effects which might arise from the comparatively large area of approximate contact presented by the rim of the bottle, although in that case also the actual contacts would doubtless be only three in number and of very small area.

With $\frac{1}{2}$ oz. in pan and surfaces treated with the hand, the carriage would move within a second or two after being placed in position, but after four or five seconds' contact would stick. After a few minutes' contact it may require $1\frac{1}{2}$ oz. in pan to start it. When the slab is breathed upon it requires, even at first, $3\frac{1}{2}$ oz. in the pan to start the motion. As soon as the breath has evaporated, $\frac{1}{2}$ oz. in pan again suffices. When the weight of the pan is included, the forces are seen to be as 1:3. When the feet stand in a pool of water the stickiness is nearly the same as with the breath, and the substitution of soapy for clean water makes little difference.

In another day's experiment paraffin (lamp) oil was used. After handling, there was free motion with 1 oz. in pan. When the feet stood in the oil, from $2\frac{1}{2}$ to 3 oz. were needed in the pan. Most of the oil was next removed by rubbing with blotting-paper until the slab looked clean. At this stage $\frac{3}{4}$ oz. in pan sufficed to start the motion. On again wetting with oil 2 oz. sufficed instead of the $2\frac{1}{2}$ oz. required before. After another cleaning with blotting-paper $\frac{1}{2}$ oz. in pan sufficed. From these results it appears that the friction is greater with a large dose than with a minute quantity of the same oil, and this is what is hard to explain. When olive oil was substituted for the paraffin oil the results were less strongly marked.

Similar experiments with a carriage standing on brass feet of about the same size and shape as the glass ones gave different results. It should, however, be noticed that the brass feet, though fairly polished, could not have been so smooth as the fine surfaces of the glass. The present carriage weighed (with its load) $6\frac{1}{2}$ oz., and on the well-handled glass side moved with $\frac{1}{4}$ oz. in pan. When the slide was breathed upon, the motion was as free as, perhaps more free than, before. And when the feet stood in a pool of water there was equal freedom. A repetition gave confirmatory results. On another day paraffin oil was tried. At the beginning $\frac{1}{4}$ oz. in pan sufficed on the handled slab. With a pool of oil

the carriage still moved with $\frac{1}{4}$ oz. in pan, but perhaps not quite so certainly. As the oil was removed with blotting-paper the motion became freer, and when the oil-film had visibly disappeared the $\frac{1}{4}$ oz. in pan could about be dispensed with. Doubtless a trace of oil remained. The blotting-paper was of course applied to the feet and legs of the carriage, as well as to the slab.

In attempting to interpret these results it is desirable to know what sort of thickness to attribute to the greasy films on handled surfaces. But this is not so easy a matter as when films are spread upon water. In an experiment made some years ago (*Phil. Mag.*, 1910, xix., 96; *Scientific Papers*, v., 538) I found that the mean thickness of the layer on a glass plate, heavily greased with fingers which had touched the hair, was about one-fifth of the wave-length of visible light, viz., about 10^{-6} mm. The thickness of the layer necessary to induce slipperiness must be a small fraction of this, possibly one-tenth, but perhaps much less. We may compare this with the thickness of olive oil required to stop the camphor movements on water, which I found to be about $\times 10^{-6}$ mm. (*Proc. Roy. Soc.*, 1890, xlvii., 364 *Scientific Papers*, iii., 349). It may well be that there is little difference in the quantities required for the two effects.

In view of the above estimate and of the probability that the point at which surface-tension begins to fall corresponds to a thickness of a single layer of molecules (*Phil. Mag.*, 1890, xlviii., 321; *Scientific Papers*, iv., 430), we see that the phenomena here in question probably lie outside the field of the usual theory of lubrication, where the layer of lubricant is assumed to be at least many molecules thick. We are rather in the region of incipient *seizing*, as is perhaps not surprising when we consider the smallness of the surfaces actually in contact. And as regards seizing there is difficulty in understanding why, when it actually occurs, rupture should ensue at another place rather than at the recently engaged surfaces.

It may perhaps be doubted whether the time is yet ripe for a full discussion of the behavior of the thinnest films, but I will take this opportunity to put forward a few remarks. Two recent French writers, Devaux (a summary of Devaux's work, dating from 1903 onwards, will be found in the *Revue Gén. d. Sciences* for Feb. 28, 1913) and Marcellin (*Ann. Phys.*, 1914, I., 19), who have made interesting contributions to the subject, accept my suggestion that the drop of tension in contaminated surfaces commences when the layer is one molecule thick; but Hardy (*Proc. Roy. Soc.*, A, 1913, lxxxviii., 319) points out a difficulty in the case of pure oleic acid, where it appears that the drop commences at a thickness of 1.3×10^{-6} mm., while thickness of a molecule should be decidedly less. Many of Devaux's observations relate to the case where the quantity of oil exceeds that required for the formation of the cono-molecular layer, and he formulates a conclusion, not accepted by Marcellin, that the thickness of the layer depends upon the existence and dimensions of the globules into which most of the superfluous oil is collected, inasmuch as experiment proves that when a layer with fine globules exists beside a layer with large globules, the former always contracts at the expense of the latter. As to this, it may be worth notice that the tension T of the contaminated surface could not be expressed as a function merely of the volume of the drop and of the two other tensions, viz., T_1 the tension of an air-oil surface and T_2 that of a water-oil surface. It would be necessary to introduce other quantities, such as gravity or molecular dimensions. I am still of the opinion formerly expressed that these complications are the result of *impurity* in the oil. If the oil were really homogeneous, Devaux's view would lead one to regard the continued existence of two sizes of globules on the same surface as impossible. What would there be to hinder the rapid growth of the smaller at the expense of the greater until equality was established? On the other hand, an impurity, present only in small proportion, would naturally experience more difficulty in finding its way about.

The importance of impurities in influencing the transformations of oil-films was insisted on long ago by Tomlinson (*Phil. Mag.*, 1863, xxvi., 187); and as regards olive oil, Miss Pockels showed that the behavior of purified oil is quite different from that of the common oil. She quotes Richter (*Nature*, xlix., 488) as expressing the opinion that the tendency of oil to spread itself on water is only due to the free oleic acid contained in it, and that if it were possible to completely purify the oil from oleic acid it would not spread at all (*Nature*, 1894, I., 223). Some confusion arises from the different meanings attached to the word "spreading." I suppose no one disputes the rapid spreading upon a clean surface which results in the formation of the invisible mono-molecular layer. Miss Pockels calls this a solution current—a rather misleading term, which has

tended to obscure the meaning of her really valuable work. It is the second kind of spreading in a thicker layer, resulting in more or less rapid subsequent transformations, which is attributed to the presence of oleic acid. Miss Pockels says:—"The Provence oil used in my experiment was shaken up twice with pure alcohol, and the rest (residue) of the latter being carefully removed, a drop of the oil was placed upon the freshly formed water-surface in a small dish by means of a brass wire previously cleaned by ignition. The oil did not really spread, but after a momentary centrifugal movement, during which several small drops were separated from it, it contracted itself in the middle of the surface, and a second drop deposited on the same vessel remained absolutely motionless." I have repeated this experiment, using oil which is believed to have come direct from Italy. A drop of this placed upon a clean water-surface at once drives dust to the boundary in forming the mono-molecular layer, and in addition flattens itself out into a disk of considerable size, which rapidly undergoes the transformations well described and figured by Devaux. The same oil, purified by means of alcohol on Miss Pockels' plan, behaves quite differently. The first spreading, driving dust to the boundary, takes place entirely as before. But the drop remains upon the water as a lens, and flattens itself out, if at all, only very slowly. Small admixtures of the original oil with the purified oil behave in an intermediate manner, flattening out slowly and allowing the beautiful transformations which follow to be observed at leisure.

Another point of importance does not appear to have been noticed. Water-surfaces on which purified olive oil stands in drops still allow the camphor movements. Very small fragments spin merrily, while larger ones by their slower movements testify to the presence of the oil. Perhaps this was the reason why in my experiments of 1890 I found the approximate, rather than the absolute, stoppage of the movements to give the sharpest results. The absolute stoppage, dependent upon the presence of impurity, might well be less defined.

If, after the deposition of a drop of purified oil, the surface be again dusted over with sulphur or talc and then touched with a very small quantity of the original oil, the dust is driven away a second time and camphor movements ceased.

The manner in which impurity operates in these phenomena merits close attention. It seems pretty clear that from pure oil water will only take a layer one molecule thick. But when oleic acid is available a further drop of tension ensues. The question arises how does this oleic acid distribute itself? Is it in substitution for the molecules of oil, or an addition to them constituting a second layer? The latter seems the more probable. Again, how does the impurity act when it leads the general mass into unstable flattened-out form? In considering such questions Laplace's theory is of little service, its fundamental postulate of forces operating over distances large in comparison with molecular dimensions being plainly violated.—*Philosophical Magazine*, xxxv., No. 206.

Recent Developments in By-Product Coking in England*

In discussing recent developments in by-product coking before the Institution of Civil Engineers, Mr. G. Blake Walker described the salient features of half a dozen of the most successful types of oven in use in this country and of the recovery plants associated with them, and also dealt with the utilization of the surplus gas generated.

He remarked that by-product ovens have now very largely taken the place of the old beehive ovens; scarcely any of the latter have been built recently, and they are destined to pass into the limbo of superseded appliances. The details of construction of all the leading types of coke-ovens show a distinct tendency to uniformity, and the most noticeable improvements in all modern plants are (1) better distribution and heating of the combustible gases, so as to ensure a more equal temperature in all parts of the oven walls; (2) separate supply of air for combustion to all the numerous burners; and (3) "direct recovery" of sulphate of ammonia.

FEATURES OF DESIGN.

The objects aimed at in all recent designs are (1) more intense and better equalization of heat in all parts of the oven walls, in order to burn off the charge more quickly and uniformly; (2) equalization of the pressure of the gas between the ovens and the heating flues; (3) reduction in the time of coking whereby a larger output of surplus gas, coke, and by-products is

obtained from a given number of ovens, with reduction in the cost of coke-making, etc.; (4) good means of inspection of the heating flues; (5) facility of regulation; (6) increased yield of ammonia and benzol; and (7) reduction of quantity of gas required for heating the ovens by the use of regenerators.

Among the benefits of by-product coking which have latterly become of importance are (1) utilization of the surplus gases for power-generation in gas engines; (2) production of illuminating gas for cities; (3) supply of gas in bulk in lieu of steam for power generation and for manufacturing and metallurgical purposes; (4) production of benzol and toluol for explosive purposes and for motor traction; (5) tar products; and (6) expansion of the production of sulphate of ammonia for fertilizing purposes. Much has also been achieved in the improvement of the mechanical arrangements in connexion with the ovens, such as the preparatory washing and the compressing of the charge of coal and the quenching and loading of the coke.

POWER-GAS.

The use of coke-oven gas for power purposes at collieries is certain to make rapid progress. Up to the present time colliery-managers have scarcely realized that a considerable supply of power from by-product coke ovens is available. In some cases there is a disposition to build waste-heat ovens and use the whole of the gases, after they have heated the ovens, under boilers. Mixed-pressure turbines, running on exhaust steam during the day and on live steam at night, have been introduced at collieries in large numbers. From the point of view of actual heat-efficiency the advantage is clearly in favor of the gas-engine and the regenerator type of oven; but the varying circumstances of collieries modify this conclusion to some extent, inasmuch as at most pits there is a quantity of unsalable fuel available. There can, however, be no doubt that such inferior material could be gasified in gas-producers with results far more advantageous than if it were burned under boilers.

WASTE HEAT FOR RAISING STEAM.

It is interesting to compare the amount of power which can be obtained by raising steam with waste heat from non-regenerator ovens and using it in steam engines, and by using the surplus gases from regenerator ovens in internal-combustion engines. The quantity of gas available depends, of course, on the quality and composition of the coal and the efficiency of the ovens, but a coal containing 30 per cent. of volatile constituents and yielding not less than 10,000 cu. ft. of gas per ton, may be taken as representative. In a battery of 50 modern by-product ovens, each having a capacity of 10 tons of damp coal, and burning off in 30 hours—say 5½ charges burnt per week—2,750 tons of coal per week will be carbonized. If these are "waste heat" ovens without regenerators there will be sufficient waste heat at about 800 deg. C. to fire six Lancashire boilers (say 30 ft. by 8 ft.), which would evaporate, say, 500 gallons of water an hour, and produce steam in non-condensing engines to the extent of about 250 h.p. each, or 1,200 h.p. in all. In addition to this there would probably be some, but not very much, surplus gas which could be used in gas-engines. If the ovens were of the regenerator type the heat would be absorbed from the waste gases in passing through the regenerators, and would be of little value for steam-raising. The highly heated air for combustion in the heating-flues of the ovens effects a great economy in the quantity of gas required for carbonization and leaves a considerable surplus for use in internal-combustion engines. As much as 60 per cent. of the scrubbed gas is sometimes available, but 40 per cent. is a very moderate proportion; 2,750 tons of coal at 10,000 cu. ft. per ton give 27,500,000 cu. ft. of gas, 40 per cent. of which is about 11,000,000 cu. ft. Reckoning 30 ft. of gas per horse-power-hour in gas-engines this quantity would give 2,182 h.p., or more than double the amount obtained by steam-raising. These figures are exceedingly rough, but they are fairly representative of results obtained in actual practice. If the gas was used in gas-engines with a consumption of only 20 cu. ft. of gas per horse-power-hour the advantage over steam would be 50 per cent. more, and probably such a consumption as 20 cu. ft. per horse-power-hour will soon be common practice.

ADVANTAGE OF GAS-ENGINES.

The calorific value of coke-oven gas varies with the coal, but is usually somewhere between 400 and 450 B.Th.U. per cu. ft. This high value was a source of great trouble in gas-engines in the early stages, but experience has enabled the makers to strengthen the weak parts, and now the internal-combustion gas-engine running on coke-oven gas can be regarded as reliable. Coke-oven gas and the exhaust-steam turbine

have in recent years very greatly assisted in the production of secondary power in collieries, which is becoming so much more necessary as mines become much more extensive than formerly and thinner seams are being worked.

The following comparison of the relative value of coke-oven gas burnt under boilers and producing steam to be used in turbines, with live gas used directly in gas-engines, has been given by Messrs. Hamel and Lueg, of Düsseldorf. Assuming a battery of 120 ovens charged daily with 6½ tons of coal each, and yielding 4,236 cu. ft. of surplus gas per ton of coal (i. e., for the battery of 120 ovens 137,700 cu. ft. an hour), with a mean calorific value of 442 B.Th.U. per cu. ft. there are 6,086,400 B.Th.U. per hour for disposal. With a heat-consumption of 11,800 units per horse-power-hour, it is possible with gas-engines to produce about 5,150 h.p. measured on the switchboard. Comparing this with the use of waste gases under boilers, and assuming a steam-pressure of 142 lb. per sq. in. with 590 deg. F. superheat at boilers, and 70 per cent. efficiency; the steam produced will be, say, 36,300 lb. per hour; deducting 10 per cent. for condensation, etc., leaves 32,670 lb. of steam to drive two steam turbo-dynamos (950 kw. each), which will produce 2,575 h.p. measured on the switchboard.

The first cost of a gas-engine plant to produce 5,150 h.p., including three machines, each of 1,200 kw., and buildings, may be put at about £33,000 and the cost of producing current at 0.064d. per kw. hour. The cost of boilers and steam plant to produce 2,575 h.p. (1,895 kw.) may be put at £25,000, and the cost of producing current 0.093d. per kw. hour. Therefore with coke-oven gas the gas-engine supplies electrical energy 31 per cent. cheaper (93:64 :: 100:69) than can be done with the steam-turbine supplied with steam from boilers heated by the gases from coke-ovens.

The annual money profit from the gas-engine plant, as compared with the steam-turbine plant, is estimated by Messrs. Hamel and Lueg to be about £3,500 in favor of the gas-engine plant, irrespective of the value of the gas. But if the calorific value of the gas is calculated, and taking 6s. per ton as the value at the pit of common boiler-coal, then the gas utilized, on the basis of its calorific value, would add £6,700 to the advantage of the gas-engine plant.

LIGHTING.

The application of by-product coke-ovens for supplying lighting-gas to cities and rural districts has been growing in Germany during the past decade, especially in the neighborhood of Essen, where a company has been formed for supplying purified gas to that city and surrounding towns as far as 70 miles away. An interesting article on the development of this application of the surplus gases appeared in *The Times Engineering Supplement*, December, 1913. Coke-ovens are now being built by gas companies, e. g., at Vienna and Birmingham, with a view to produce a metallurgical coke and at the same time an equal yield of gas and residuals. The earliest installation on a large scale was in connection with the supply of lighting and power gas to the city of Boston, U. S. A., where at the Everitt works there were erected, in 1901, 100 coke-ovens specially for this purpose; and the number has since been increased.

It is claimed that very considerable economies can be secured by producing gas for lighting purposes in coke-ovens—i. e., large retorts—as compared with producing it in a large number of comparatively small retorts, as is the present practice. Mr. G. Stanley Cooper, in 1914, summarized the advantages of bulk carbonization as follows:—(1) The labor costs are reduced considerably, owing to the fewer charging and discharging operations; (2) coke-breeze and low-grade fuel may be used for heating the ovens; and (3) a good metallurgical coke and a superior tar are produced in coke-ovens designed for town-lighting purposes, where none of the gas from the ovens is used for heating them.

The gas for heating is producer-gas obtained from a Kerpely producer, which is of the revolving-grate type. At Birmingham, Mond producers have given excellent results. The charging of the ovens can be done in the daytime, and thus they are all closed and producing gas during the time when the greatest quantity is required. The ovens are charged and drawn every 24 hours.

In western Germany the use of coke-oven gas for lighting is making great strides. In Rhineland and Westphalia, Weel, Mülheim on the Ruhr, Velbert, Wulfrath, Barmen, etc., take nearly 1,000 million cu. ft. of gas. Essen, Oberhausen, Osterfeld, Bottrop, Gelsenkirchen, Herne, Bochum, Castrop, Witten, etc., take 1,872 million cu. ft.; and there are other towns supplied from coke-ovens. The price paid by municipalities for coke-oven (purified) gas is under 9d. per 1,000 cu. ft.

**Engineering Supplement of the London Times.*

Reflecting Prisms*

Their Use in Place of Mirrors and the Geometry of Various Forms

By Naval Instructor T. Y. Baker, R.N.

THERE are many purposes for which prisms may be used as reflectors in optical instruments, and the author has thought that it may be of interest to the Society to have a few facts and suggestions put before its members.

In many cases it is preferable to use a prism in place of mirrors. There is no need to silver the surface in some cases; they are often easier to mount, and for certain types of prism give a definite angle of deflection. The prismatic binocular is a case in point. If it had been necessary to mount four mirrors inside the tubes and keep them in proper adjustment, the prismatic binocular would not exist at the present day—except, perhaps, in a museum.

In this paper it is proposed to deal with prisms in which the reflections are all in one plane. The geometry of the ray-paths in the more general case, where the reflecting surfaces are inclined at all sorts of angles like the facets of a crystal, is exceedingly complicated to work, and still more difficult to illustrate by diagrams.

The reflections being all in one plane, and the geometry consequently two-dimensional, the prism will act as a simple mirror, or will deflect all rays through the same angle, according as whether the number of reflecting surfaces is odd or even.

Single Reflection Prisms.—The only one which calls for much comment is the one in the form of a right-angled isosceles triangle—the binocular prism—in which the slant face is used as a reflector. This prism can be used to invert a bundle of rays without deflection, or to deflect through various angles just as a plain mirror would. It has this advantage over the latter, that, owing to the refraction produced at the entrant face of the prism (which is nullified by corresponding refraction on emergence), it is possible to obtain reflection of a beam which comes in from behind the reflecting face. (Fig. 1, dotted line.)

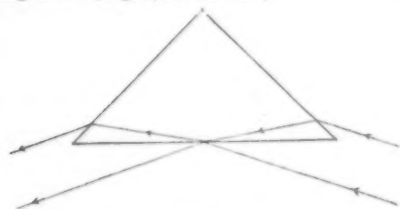


Fig. 3

In order to get a pure reflection effect without any refraction, it is necessary that the two base angles of the prism should be equal, though not necessarily exactly 45°. If the image of the prism formed by reflection in the base be the dotted portion of Fig. 2, it is clear that the ray which is actually O A B C P would pass along O A B C' P' if we had a block of glass X N Y N' with parallel faces X N and Y N'. If these two lines are not parallel—which is equivalent to saying that the base angles of the prism are not equal—the ray will emerge from C' in a slightly different direction, C'Q', and correspondingly the emergent ray through the prism would be C Q instead of C P.

The deviation Q C P or Q' C' P' can be expressed as

$$\phi \{ \sec \theta (n^2 - \sin^2 \theta) - 1 \}$$

where θ is the angle which the ray O A makes with the normal to the face at A and ϕ is the difference of the base angles. This deviation increases rapidly with θ ; for instance, it is twice as great at 60° as at 45°. Consequently it is not possible to use such a mirror for measurement of deflection in the way in which a sextant mirror is used unless the suitable correction is made at every point along the angle scale.

Possibly prisms might be manufactured so as to be reasonably isosceles, particularly as there is a very simple test for such a condition. If a distant point of light be viewed by very oblique reflection in the base of the prism, a second image can also be seen by reflection at the inside of the base. The base surface is, in fact, reflecting light from the object on both sides at once (Fig. 3). The two images will coincide only if the base angles are equal; alternatively they will be separated by an angle given by the formula above.

A prism of this type is used as an azimuth mirror with the mariner's compass, being mounted so as to rotate round a horizontal axis and to throw light from the sun down through a lens and so form an image of the sun upon the compass card.

The position on which the axis is fixed relatively to the prism is of some importance in order that the maximum amount of light may be transmitted through the lens. The central ray of the bundle is clearly the one which is reflected at the middle point of the base, and the caustic of the emergent central ray is shown in Fig. 4. If it is desired only to use the prism with its base unsilvered, then the lower part of the caustic will be the portion with which we are concerned, and the centre of rotation should be an approximate centre of curvature of the lower portion of the caustic in

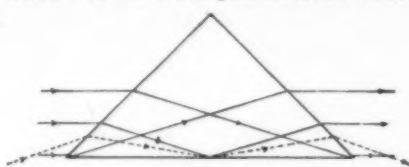


Fig. 1

question. On the other hand, if a wider range of use is required, and the surface is silvered, the centre of rotation would be better placed near the cusp of the caustic.

Another form of prism, in which the ray is reflected once only, is used by M. Driencourt in the Astrolabe bearing his name. This instrument is for the determination of the instant when a star reaches an altitude of 60° above the horizon, and the method by which this is done is shown in Fig. 5. Strictly speaking, this is not a single reflection prism in the sense that the previous one is. Rotation round an axis perpendicular

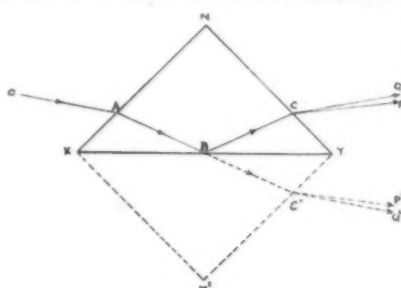


Fig. 2

to the plane of the paper will deflect the emergent beams by the same amount in each case, so that the two images of the star would remain in contact although they would move about in the field of view. Theoretically such a prism should be exactly equilateral, but from the point of view of the observer, it might be a distinct advantage if the angles differed slightly from one another as in that case the prism could be used with each face successively vertical, and consequently three contacts between the two images of the star obtained instead of one. The mean of the time of the three observations would be exactly the instant at which the star's altitude was 60°.

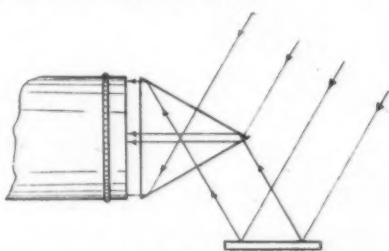


Fig. 5

Double Reflection Prisms.—All prisms in this class will deflect light through double the angle between the two faces, provided there is not refraction error due to bad design or bad workmanship.

The forms which such prisms may take vary considerably, and for the purposes of illustration the best forms for every 15° of angle from 0° to 90° are shown in Fig. 6. There are certain points connected with the design of all these which are identical, and may be referred to in a convenient form by the use of a strip of folded paper to represent the bundle of rays. If we take the first of the series it is clear that the path of the outside rays of the bundle is the same as the edges of a strip of paper the same width as the bundle folded at angles of 45° on the dotted lines AD and BC (Fig. 7). If the strip of paper is opened out it is clear that any ray of light which crosses the entrant face between A

and B and the emergent face between C and D will also pass through the prism. The limiting ray which can get through is that represented by the line A C, so that, for most purposes, it is desirable to design the prisms so that the ratio of the breadth of the strip to its length may be as large as possible.

It will be convenient, in fact, to denote the angle A C B as the aperture of the prism. The designs of prisms shown in Fig. 6 all aim at making this aperture as large as possible. For the Zero reflection prism explained by Fig. 7 this angle is $\tan^{-1} \frac{1}{2}$ or approximately 26°.

The corresponding folding for 90°, the optical square, is also shown in Fig. 7.

The first three prisms of the series are designed on the same plan of which the general type is shown in Fig. 8. The angle of deflection is 4a, and the suitable angles are all marked so as to give maximum aperture. For the 45° prism this form becomes unsuitable, as a more compact form can be obtained, one face acting both as transmitter and reflector of light. Curiously, the 60° prism follows the same form as shown in Fig. 8, but as, in such case, the first reflecting surface and the emergent face make a continuous surface, the aperture is really double that given by the general case above.

After 60° the method of arrangement has to be altered in order to avoid re-entrant angles, and the apertures are reduced both with the 75° and the 90° prisms. It will be seen that in both cases there is symmetry with respect to a certain line, and consequently a maximum aperture.

Angles above 90° have not been all worked out in detail, but there are two types which possess maximum aperture for the same reason. These are 120° and 180°, which are illustrated in Fig. 9.

In all these prisms the entrant and emergent faces are placed at right angles to the beam so that the re-

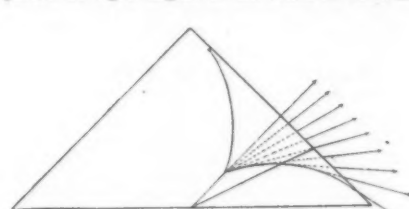


Fig. 4

fraction errors which may arise owing to workmanship, will be a minimum. The aperture discussed above has in all cases been the aperture in the prism. This is not the same as the external aperture, inasmuch as the extreme ray which can pass through the prism will pass the entrant and emergent faces obliquely, and will consequently be refracted at these two places.

The values of the internal and external apertures are tabulated below, the index of the glass being taken as $n_D = 1.5180$.

	Internal Angular Aperture.	External Angular Aperture.
0°	26½°	42½°
15°	23¾°	37½°
30°	21°	33°
45°	30½°	50¼°
60°	30°	49½°
75°	13¾°	20¼°
90°	16¼°	25¼°
120°	16°	25°
180°	26¼°	42½°

Triple Reflection Prisms.—If light traverses one face A B (Fig. 10) of an equilateral triangle A B C normally, it can be reflected at C B, then at A C, a third time at C B and will retrace its original path. To do this the side A C should be silvered, although a faint reflection could be obtained with an unsilvered surface. This affords a method of measuring the errors of a 60° prism. If the two base angles are 60— α and 60— β and an auto-collimating telescope be placed in front of the face A B, three images will be obtained. Firstly the direct reflection from A B, secondly the image by triple reflection as above, and thirdly by triple reflection starting from A C.

The separation of two and three from one will be $2n(\alpha + 2\beta)$ and $2n(2\alpha + \beta)$. If these are measured, α and β can be obtained.

Another form of triple reflecting prism which might be of considerable use is one whose angles are 30°, 30°

*Transactions of the Optical Society (London).

and 120° (Fig. 11). The bundle of rays incident normally on the long side will emerge parallel and clear of the entrant bundle, a small deviation from the normal will, of course, involve an equal deviation, on the opposite side, of the emergent bundle. Such a prism might take the place of the horizon mirror in a sextant, which has to be set at an angle of about 75° with the telescope's axis, in order that the light between the two mirrors may not be cut off by the telescope tube.

By using such a prism in place of the mirrors the aperture could be very considerably enlarged, practically trebled. Further, the range of angles which can be measured by the sextant, now extending to 150° , could be increased.

Color Vision

No theory of color vision was free from objections. The Young-Helmholtz theory, however, gave at least a simple representation of the facts of color vision and color blindness. According to that theory there were three elements of color sensation, corresponding to three distinct physiological actions, one for each of the three primary colors, by the aid of which any color could be matched. It was hardly necessary to assume with Helmholtz three distinct sets of nerves. It was frequently supposed that light entering the eye produced certain photochemical changes in the retina resulting in the sensation of light. Dr. Allen thinks it sufficient to assume photoelectricity of the substances in the rods and cones; that electrification would separate electrons in the nerve cells, and set up nervous impulses to the sensorium, and the changes in the retina would be identical in nature with those in a phosphorescent substance or in the photographic plate. The after-image (seen in the dark after looking at bright objects) would be a phosphorescence, the excitation of the retina being due to the separation of the electrons, the after-image to their return. In support of this view he referred to the production of light by electric stimulus or by sudden pressure on the eye; to the asserted visibility of Röntgen rays to dark-adapted eyes; to the curves of the sensitiveness of the eye to rays of different wave-lengths which resemble photoelectric curves for those wave-lengths (H. E. Ives); and to selective absorption and color blindness. A pigment appeared red, because it absorbed (subtracts) the green and blue rays from the white light received. A color-blind man unable to see red resembled a man looking through green-blue ("minus red") spectacles. Dr. Allen in this connection showed some experiments due to C. R. Gibson of Dublin. He had a set of silk skeins in rainbow

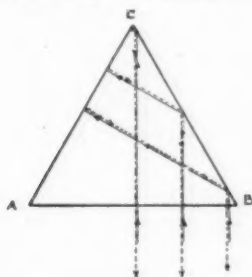


Fig. 10

colors. Illuminated by the arc beam passed through a screen of green-signal glass, these colors looked strange, of course, the yellow appearing green, *c. g.*, when Gibson reproduced these colors on wool skeins, however, the hues appeared changed with the same green illumination; the yellow remained yellow, and that was because the yellow was really a phosphorescence color. The point is scientifically and technically interesting; the dyes used were not specified. Whether this view of color vision will satisfy physiologists, remains to be seen.—*Engineering*.

The Perception of Sound

ALTHOUGH the pitch of a particular tone is, say, 640 d. v. per second, it is not necessary that, in order to recognise it, we should listen to that tone for a whole second of time. Prof. McKendrick many years ago

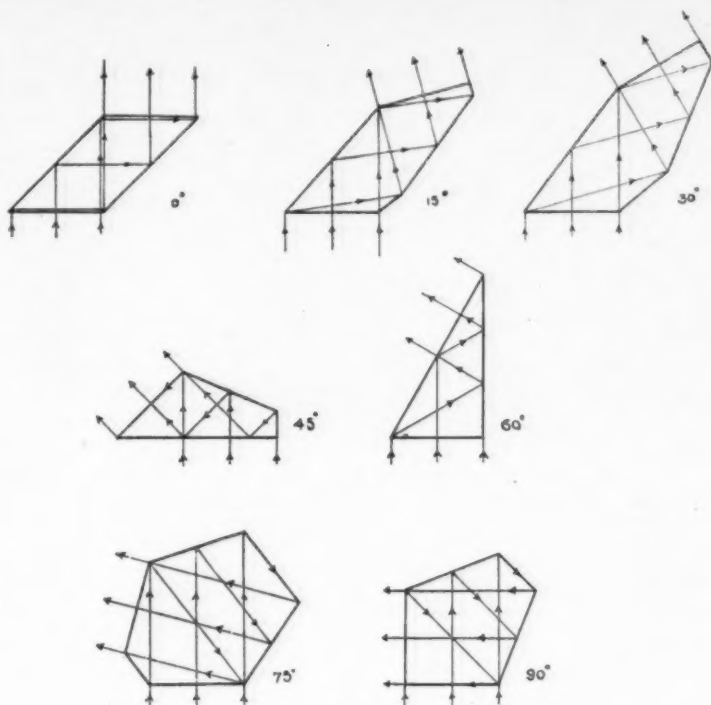


Fig. 6

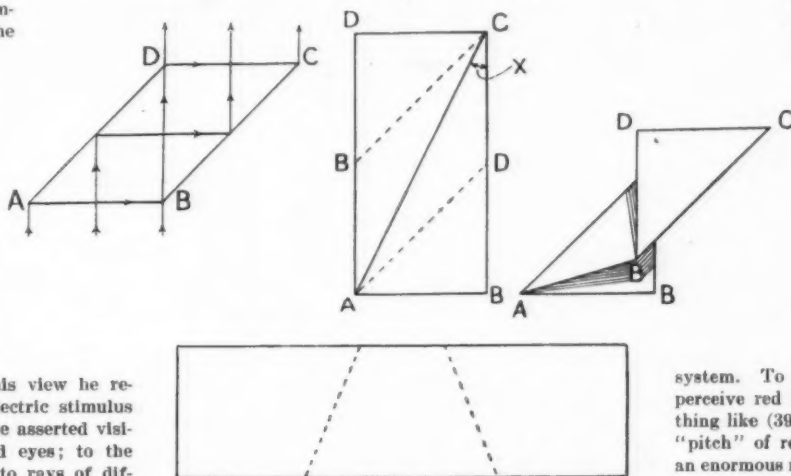


Fig. 7

demonstrated that we could recognise as distinct from its predecessor and successor a note in a musical composition if it were listened to for only $1/64$ th of a second. In such a case this would mean that only ten con-

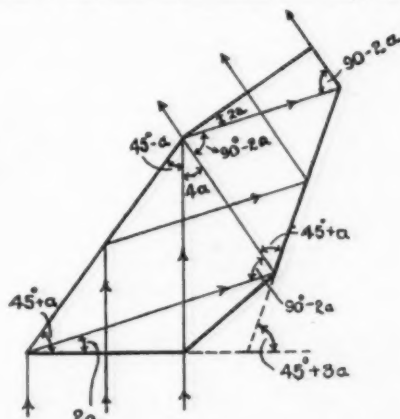


Fig. 8

densations would affect the organ of Corti, and presumably only ten nerve-impulses ascend the auditory nerve. Prof. McKendrick, with whom it was my privilege to be associated at that time, studied the

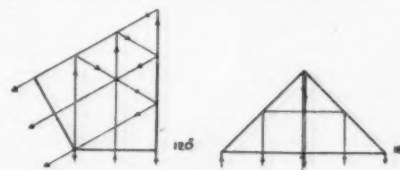


Fig. 9

surface of the wax-cylinder records of musical compositions recorded for reproduction by the phonograph.

Since the speed of rotation of the cylinder was known, the number of impressions in the wax corresponding with each of a series of tones could be ascertained; and it was found that, in order to recognise any given tone, it was only necessary to "hear" that tone for not longer than $1/64$ th of a second. If I remember correctly, a shorter period still was in some cases demonstrated to be sufficient.

Now if, say, $1/100$ th of a second is long enough, it is clear that the hearing of quite high tones could be effected by a comparatively small number of vibrations or disturbances in the internal ear and of subsequent impulses in the nerve.

A tone of 2,000 d. v. per second could be recognised by 20 impulses, and one of 10,000 pitch by 100, and so on. Apparently the auditory nerve is competent to transmit individual impulses of that order of frequency.

It seems to me that attention to this point will make the problem of hearing rather simpler than at first it appears by removing the necessity for believing that, in order to appreciate a note of a given pitch, we require to have the auditory nerve transmitting the large number of impulses corresponding with the large number of vibrations which, according to physicists, is the pitch or number per second of that note. In other words, the different tones in a musical composition follow one another with such rapidity that no particular note is produced for a whole second, and, therefore, not perceived for a whole second.

But, on the other hand, it is clear that we can listen to a high-pitched note for a second or for a minute or for any length of time. When we are hearing a note of 20,000 d. v. per second, we are almost certainly not receiving 20,000 impulses per second into the central nervous

system. To take an analogy from vision: when we perceive red light, we are certainly not receiving anything like (395×10^9) impulses per second, which is the "pitch" of red light. If, in seeing colored light, such an enormous number of vibrations in the ether affect the retina, there must be something of a very different character as regards frequency, which, ascending the optic nerve, so stimulates the visual centre that we see colored light.

We have in perceptual consciousness qualitative differences, an ever-present problem of psycho-physics; and no one has ever suggested that our optic nerves and visual centres are dealing with impulses at many millions a second. Why, then, may we not apply the same reasoning to the ear?

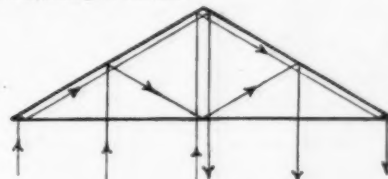


Fig. 11

When we are listening to all possible tones from, say, 1,000 d. v. per second pitch to 40,000, may we not somehow have in consciousness qualitative differences corresponding with objective quantitative (arithmetical) differences? We cannot, apparently, be more definite than this.

In the case of the eye there is no conceivable possibility of an identity between the rhythm of optic-nerve impulses and that of the vibrations of the ether; is it not by analogy probable that neither is there any direct correspondence between the auditory nerve-impulses and the periodicity of sonorous vibrations?—*D. Fraser Harris in Nature*.

Strontium in Copper Castings

THE addition of strontium to copper for making copper castings is said to result in the production of an alloy which is harder than the ordinary copper casting, and one from which all dissolved gases are eliminated, causing the castings to be free from blow-holes.—*The Engineer*.

Agricultural Fertilizers*

The Raw Materials, Their Source and Characteristics

PHOSPHORUS, in the elemental condition, is a very active substance, but in the form of compounds present in the soil it loses its vigor and enters quietly into the structure of plants and through them into animals. In the former it is found in largest quantity in the seed and fruit; while in the latter it is an important constituent of bone and is present also in the brain and associated nervous matter. To man, therefore, it is particularly important. Soils containing no compounds of phosphorus or else depleted of those once present, demand an addition of such material to be productive.

The basis of commercial fertilizers and the ingredient of greatest bulk to which the other more concentrated constituents are added, is an impure compound of phosphorus occurring in nature in large masses and known as phosphate rock. The United States is the world's greatest producer of this material, and within her borders lie the largest reserves thus far discovered. Some 10 years ago the quantity of phosphate rock in sight throughout the world was not sufficient to meet the growing agricultural needs for 100 years, and the situation was said to represent "man's weakest hold on the universe"; but the recent discovery of our western phosphate fields and an appreciation of the size of deposits in northern Africa have extended this limit many centuries hence.

There are other sources of the phosphorus content of fertilizers, among which organic substances such as fish scrap, cottonseed meal, bones, slaughterhouse refuse (prepared and sold in a form called tankage), and guano are the most important; but most of these substances are in strong demand for other purposes, and the growing price is fast reducing their economic availability for fertilizer manufacture. This, too, in spite of the fact that most of them have also a nitrogen content and therefore perform a double function when added to fertilizers.

At the outbreak of the European war, we were obtaining from abroad, in addition to a small importation of phosphate rock, inconsequential supplies of two other phosphatic products. These were basic or Thomas slag and the mineral apatite. Basic slag is a by-product from the smelting of iron ores rich in phosphorus, by a process which relegates this usually deleterious constituent to a mass of slag which is thereby so enriched in phosphorus that it can be ground and used as a fertilizer. This process has developed principally in Europe, where large deposits of phosphorus-rich iron ore have been rendered available by it; in fact, the iron supply of Germany is drawn largely from such deposits in Lorraine, divided between German Lorraine and captured French Lorraine, which have also furnished most of the phosphate fertilizer used in Germany since the supply of phosphate rock from the United States was cut off. Apatite is a mineral mined to a limited extent in Canada; but its deposits are too restricted in size ever to be significant, in spite of the fact that scattered microscopic crystals of apatite are present in practically all igneous rocks and represent the ultimate source of the phosphoric acid or soils as well as of that now found concentrated in phosphate rock.

In the United States, therefore, phosphate rock is and must remain the dominant source of fertilizer phosphorus. The chief producer at present is Florida, which contributes normally 75 per cent. of our annual output of 3,000,000 tons. There this material forms three types of deposits, known as rock phosphate, pebble phosphate, and soft phosphate; but all are essentially flat-lying, superficial beds of solid rock or loose, bowdery material, representing chiefly a concentration of phosphatic substance through the superior solubility and removal of the associated rock. The nature of these deposits enables them to be economically worked by means of large open pits, and their position near seaboard affords cheap transportation to manufacturing centers such as Savannah, Charleston, Norfolk, and others, as well as ready exportation to Europe.

Other deposits of interest and value as being within reach of the eastern fertilizer centers lie in South Carolina, Tennessee, Kentucky, and Arkansas, but these are smaller in output as well as in reserves, and, with the exception of those in South Carolina, less favorably located than the Florida deposits. All the eastern deposits combined, however, would sustain the increasing domestic consumption but a few decades; and hence unusual interest attaches to the discovery in 1906 that a belt of country, later found to extend from near Salt

Lake City to Helena, Mont., includes a number of beds of phosphate rock. A careful survey of this region by the United States Geological Survey has disclosed a measurable tonnage of phosphate rock far greater than known elsewhere in the world—and the field is not yet thoroughly explored in its entirety—but the material is not high-grade throughout, and the supply, while large, is by no means inexhaustible. The western deposits have not as yet been worked to any significant extent, owing to the fact that there is practically no local demand for fertilizers, while a long and costly freight haul walls off eastern markets. Their development awaits a local need or exhaustion of eastern deposits, but may be accelerated by the successful application of a process now known for extracting the phosphoric acid in concentrated form so as to reduce the freight on unit values. Possibilities of a local phosphate industry are opening up in connection with the manufacture of sulphuric acid from waste smelter gases at such near-by mining centers as Butte, Mont.

Phosphate rock in the crude condition is not suitable for fertilizer purposes, even if finely ground, because its valuable constituent is bound up in a relatively insoluble form. Hence the crude material is treated with about an equal amount of sulphuric acid, which produces a substance called acid phosphate, in which nearly all the phosphorus has been changed to a form suitable for plant food. The fertilizer industry therefore is closely associated with the manufacture of sulphuric acid, consuming indeed just about half of the several million tons of this material made each year, the rest being utilized in a hundred and one other industries; for sulphuric acid is one of the most widely used of chemical substances.

The need of large quantities of sulphuric acid gives us one key to the localization of the fertilizer industry, since most of the acid used for fertilizer purposes is made from pyrite, a sulphur-bearing mineral, brought in bulk by return bound Mediterranean freighters, which stop at the port of Huelva in Spain and take on as ballast this mineral, mined cheaply in the great mines of Rio Tinto in that country. Another reason for the concentration of the fertilizer industry in the southeastern States is, of course, the fact that the soils there are lean and they also have been long under cultivation and are drained of their plant food.

The cutting off, in part, of the supplies of Spanish pyrite by the unrestricted submarine warfare of 1917 has considerably upset the fertilizer industry by endangering its sulphuric acid source; and this condition has led to a limited development of some of the numerous small pyrite and pyrrhotite deposits of the Eastern States, never before able to compete with the Spanish pyrite. It has also directed attention to the sulphur deposits of Louisiana and Texas as a possible source of raw material, although these deposits, while cheaply worked, have been thus far shipped for other uses owing to the purity of their product.

NITROGEN.

It is not intended to indicate the relative importance of the three major plant foods by the order in which they are taken up here; their functions, indeed, are different, and they are consequently not open to comparison in this respect. Nitrogen, however, is the element customarily cited first on the labels of commercial fertilizers, and it may conveniently be taken up next. Nitrogen, of course, does not appear in fertilizers in the elemental or gaseous condition, but in the form of various chemical compounds, such as sodium nitrate (also called Chile saltpeter, or merely nitrate), ammonia, ammonium sulphate, and complex organic compounds; all, in short, more or less soluble in the weak acids which operate around the roots of plants and convey the plant food in solution to its destination.

Nitrogen contributes stalk growth to the plant. When it finds its way to the bodies of animals it enters into the composition of the protoid compounds, which are present in every cell, playing a part of essential importance in the life processes. Unlike phosphorus and potassium, nitrogen is not a product furnished by the weathering of rocks, but its source is the atmosphere, which, indeed, is composed to the extent of about 78 per cent. of this gas. But so long as neither plants nor animals are adapted for breathing in the required nitrogen direct, a roundabout method has been evolved whereby microscopic organisms known as bacteria, present on the roots of plants, transform the atmospheric nitrogen into compounds of suitable nature for assimilation. A class of plants the legumes, of which

clover is a familiar example, has the ability of fixing nitrogen in this way to an unusual degree; and a crop or so of such plants, when turned back into the soil, form a common expedient for increasing the nitrogen content of farm land.

The most prominent source of nitrogen has long been sodium nitrate, a natural salt occurring in quantity in the deserts of northern Chile. It is found in the form of a thin blanket or bed which underlies more or less continuously a strip of country inclosed between the Coast Range and the Andes, and extending for several hundred miles southward from the confines of Peru. This occurrence was discovered in 1821, and its exploitation led directly to the Peruvian-Chilean war of 1879-1882, which resulted in the acquisition by the latter country of the coastal portion of Bolivia and the Peruvian province of Tarapaca. Its continued development has made Chile a stable and prosperous nation, as a result of the governmental income from the royalty imposed on exports; and for the past half century the whole world has looked to this locality for its nitrogen supply. Such has been the case because nowhere else on the globe have geological conditions conspired to produce a vast accumulation of nitrogen fixed in usable form. Even here these valuable deposits owe their existence to the total absence of rain.

Chilean nitrate has become of greater importance to the explosive industry than to the manufacture of fertilizer, owing to the fact that it is the chief source of nitric acid used in making practically all explosives. In this connection, however, it should be remembered that explosives are not solely employed in times of war, but their utilization is also widespread in peace time in the blasting operations upon which modern mining and railroad construction depend. Without the Chilean deposits, it would appear, the world would have been deterred for many decades, if not longer, in reaching the point of industrial development in which it is now involved, so far-reaching can be the effect of a simple mineral deposit.

The fertilizer industry, therefore, in order to obtain its share of Chilean nitrate, has been forced to meet a price raised by this counter industrial demand and the generous royalty imposed by the Chilean Government, and only mitigated by the provision of nature in rendering the deposits of such character as to be cheaply worked. And when we add to this the recent demands put upon this mineral deposit by the unparalleled needs of the allied Governments in regard to war explosives and consider in addition the circumstance of a constantly decreasing ocean tonnage growing out of the submarine warfare we see that the problem of Chilean nitrate from a fertilizer standpoint is not easy of solution. We gain some idea at the same time why the "nitrogen question," which sprang into prominence over a year ago, still holds well to the forefront.

The fertilizer industry, seeing its most convenient nitrogen source drawn upon by another large industry and then upon the coming of war largely appropriated by that activity, has concerned itself deeply with other sources of supply. The largest source of fertilizer nitrogen, therefore, even before the war, had become a number of organic products, such as tankage, fish scrap, and cottonseed meal, produced in this country, and guano imported from almost depleted deposits off the Pacific coast of South America. But with the coming of war other demands have been put upon most of these products, raising their price. In regard to cottonseed meal in particular, it has gradually become apparent that it is indirect and wasteful to add this material to soil to increase food production when it can be fed directly to cattle to accomplish more effectively the same purpose and then be later recovered in almost its entirety for fertilizing use in the form of manure. It would seem, therefore, that opposing economic demands are gradually withdrawing organic nitrogen of the kinds enumerated from the fertilizer industry.

The third major source of nitrogen, as yet only partly developed, is coal. The nitrogen in coal might be termed fossilized nitrogen in that it represents a portion of the nitrogen of the atmosphere withdrawn in ages past by coal-forming plants and now fixed in the resultant coal to the extent on the average of over 20 pounds of nitrogen to each ton of coal. When the coal is burned

*Not so much in a numerical as in an economic sense. While such figures as may be obtained seem to indicate that as much Chilean nitrate is going into fertilizers in this country in 1917 as in 1913, the heavy war demands for this substance have worked against its effective (i. e., cheap) utilization in fertilizers.

*From the Mineral Industries of the United States; National Museum Bulletin 102, part 2. Smithsonian Institution.

this nitrogen is given back to the atmosphere and lost. If the nitrogen were recovered from all the coal consumed throughout the world, the supply would more than offset the total needs of industry during the era of extensive coal utilization, which is limited, however, to a short period of centuries.

But recovery of nitrogen from all the coal used is an impracticable thing under present usage. In this country in 1913 we saved the nitrogen from only 3 per cent. of the coal mined. That figure was perhaps as high as economic conditions permitted at that time; it is a little greater today, and it is subject to considerable increase in the future, provided the whole fabric of coal by-product development advances without dismemberment. This will be clearer if we consider that coal at present serves two prime functions—it furnishes fuel to produce heat and power and it supplies the coke required in the process of changing iron ores into metallic iron.¹ Roughly, 12 per cent. of the coal mined in the United States in 1913 was made into coke; that is, 60,000,000 tons of coal was so treated. Of this quantity, nitrogen was recovered from only a quarter, yet that nitrogen supplied a significant part of our total needs.

Coke is coal freed of certain liquids and gases which are given off when the coal is heated without access of air. The coke industry grew up many decades ago around Pittsburgh, because of the occurrence of suitable coal in that locality, establishing there our great iron and steel industry. At first the coke was made without regard to saving the volatile portion, the process being carried out in the so-called beehive ovens, which not only waste valuable constituents of the coal but actually consume a considerable part of the coal itself. To say that this method should never have been utilized, or should now be stopped by drastic means, would be to overlook the fact that progress in such matters can scarcely exceed the industrial demands for the products involved. This country is just now in a transitional state in this respect; an increasing amount of coal is being made into coke in a modern type of oven, known as the retort or by-product oven, which not only produces a maximum of coke but at the same time yields gas, nitrogen in the form of ammonia,² and coal tar, this last convertible into dyes, medicinal preparations, explosives, and other compounds. Thus the production of nitrogen from coal is closely dependent upon the production of its associated by-products, and is limited at any given time by the demand for coke on the part of the iron industry and the demand for other coal products on the part of other industries. The proper development of coal-product nitrogen must, therefore, go hand in hand with a well-balanced growth of the entire coal-products industry; and to reach its full fruition, must expand beyond the limits imposed by the needs for metallurgical coke through a gradual extension of the uses of coke to fuel and power purposes.

But coal-product nitrogen, while the most promising partly developed source of nitrogen in this country today and open to considerable and somewhat rapid expansion, must nevertheless remain a transient source, if transient be interpreted to represent a few centuries. The ultimate source, it would seem, upon which the world must eventually depend is the atmosphere. Coal-product nitrogen, indeed, on the last analysis, is merely atmospheric nitrogen rendered more readily available by geological processes of past ages, and is therefore a tide-over from a purely mineral source to the atmosphere.

The world, in fact, is already turning to the atmosphere for a significant part of its nitrogen. Three processes for securing nitrogen from the air have proved successful under different circumstances, and other processes are in the course of experimentation, if not actual development. The three processes which have proved practicable under certain limitations are the arc process, the cyanamid process, and the Haber process.

The arc process produces nitric acid by means of the combustion of nitrogen and oxygen in the electric arc. It requires large quantities of cheap electric power and has proved successful in Norway, where hydroelectric power abounds. Its product for fertilizer use must be neutralized, and the resultant substance, calcium nitrate, is not adaptable to machine distribution as practiced in the United States.

The cyanamid process depends upon the combination of nitrogen with calcium carbide; it requires less power than the arc process; and its product, cyanamid, is directly suitable for use as fertilizer or convertible to ammonia compounds. The product may also be ox-

dized to nitric acid by a process successfully applied abroad. An important cyanamid industry has developed on Canadian soil at Niagara Falls, and the process has met success in Germany.

The Haber process involves the direct synthesis of nitrogen and hydrogen to ammonia. The process is successfully employed in Germany, where the product is oxidized to nitric acid for munitions manufacture. The technical details of the process are complicated and involved.

It becomes apparent, therefore, that the merits of the three processes are somewhat dissimilar, and they are not all equally adapted to the same conditions. It might be mentioned also that Germany apparently anticipated that a prolonged war would be impossible without drawing on atmospheric nitrogen, inasmuch as Chilean nitrate could be readily barred, while coal-product and organic nitrogen could not meet her wartime needs. At least it is significant that war was declared directly after the successful development of the Haber and cyanamid processes in that country, and it is certain that there it could not have progressed as far as it did without them.

This completes the list of sources from which we at present obtain nitrogen on an organized scale. Peat is a nitrogenous substance and is used locally to some extent as a fertilizer. The artificial bacterial inoculation of peat to increase its nitrogen content opens up interesting possibilities, now in process of experimentation; while an even more direct use of nitrogen-fixing bacteria, cultivated in a medium of organic waste, "provides a less visionary project than might appear offhand." On general grounds it seems quite logical to expect that, inasmuch as bacterial action is the method followed by nature in providing the nitrogen compounds required by plants, this process speeded up and controlled by man will furnish the ultimate solution of the fertilizer aspect of the nitrogen problem. If so, this will serve to illustrate again that no problem in this field can be solved at one stroke, but rather requires an evolution of successive solutions, each adapted to the current industrial and economic situation.

Finally, in regard to nitrogen, we have two products, garbage and sewage, now to a large extent wasted, although possessing a distinct fertilizing value. We may look forward to an increasing number of municipal plants employed in rendering these materials suitable for use. But development along this line for proper fruition must be co-ordinated with all related activities.

POTASSIUM.

The third major plant food is potassium, which, however, like phosphorus and nitrogen, appears in neither fertilizers nor soils in the simple elemental condition, but in the form of various compounds or salts, of which the most important are potassium carbonate, potassium chloride, and potassium sulphate. The term "potash" refers strictly to potassium oxide, used for calculating these compounds to a common basis; but the term is also employed in a loose manner to embrace the potassium salts in general.

Potassium contributes stalk strength and kernel filling to the growing plant. It is present in normal soils partly in the form of a soluble compound, potassium carbonate, produced during the course of soil formation by the chemical decay of complex silicate minerals present in the parent rocks. Where potassium in soluble form is lacking, due to special geological conditions of soil formation, or where it is withdrawn rapidly by continuous crop production, it must be added to the soil from an external source.

Potassium is a very common element. Only seven others are more abundant. There is more potash in the crust of the earth than there is water upon it. The trouble is that, unlike water, potassium compounds are concentrated at only a few places on the globe; and at one of these, the famous Stassfurt deposits in Prussian Saxony, the concentration is in such richness and bulk that this single deposit has for many decades dominated the world in regard to this valuable element. It had to be so, for the problem was not to get potash, but to get cheap potash.

The German deposits were discovered some 60 years ago in connection with deep borings put down in search of rock-salt beds, the region having previously been productive of that more common substance; and as the demand for potash salts grew, developments opened up beds and lenses of practically pure potash minerals of remarkable extent and in such form as to be very readily and cheaply mined. While recent figures are not available as to the tonnage of potash in sight in these deposits, there is no question but that the supply is sufficient to meet the needs of the whole world for a very long period.

The localization of an indispensable mineral deposit

within the confines of a single country is in many respects disadvantageous for other countries, at least under the existing order of things. The United States came to a realization of that fact in a general way some years ago, as a result of which both the Agricultural Department and the Geological Survey began a systematic search for domestic sources of supply; but not until the present war cut off entirely the imports of German potash did this country come to a full appreciation of the significance of the situation. As the result, therefore, partly of governmental anticipation (the only conspicuous example of such a course of action in the field of mineral products) and partly of war-inspired activity growing out of soaring potash prices, this country is now producing from a variety of sources a significant but still inadequate supply.

Practically the only domestic source of potash at the outbreak of the European war was a small recovery made from wood ashes, chiefly in connection with the lumbering industry in Michigan and Wisconsin; but the potentialities in this regard, while important to certain localities, are not great.

The most productive domestic potash enterprise is the recovery of potash salts from some of the alkali lakes of the West, whose waters have been found to be relatively rich in potassium compounds. Jesse Lake in western Nebraska is an interesting example, because its potash is supposed to have been leached from the adjacent plains following extensive forest fires, representing a natural wood-ash extraction. Searles Lake in California has attracted considerable attention because of the reputed tonnage of potash present; its tonnage is undoubtedly great, but a complex assemblage of salts is found, so that its development is proceeding along the lines of effecting a recovery of the several valuable products. Owens Lake, Cal., several lakes in Oregon, and a number of other somewhat similar sources offer potash possibilities, as does also the bitterns or mother liquor residues in connection with the solar salt plants of Great Salt Lake and the Pacific coast. Considerable drilling exploration has been carried on in favorable geological horizons in Texas, Oklahoma, and other localities carrying strata of arid-climate origin, with the hope of finding potash beds in association, but while results of some little promise have been obtained in a few places, no significant potentialities have been demonstrated.

The mineral alunite, a potassium aluminum sulphate, occurring in deposits of moderate size in Utah, is producing at a small but steady rate, and represents an interesting example of a mineral now in demand which was looked upon a few years ago as worthless.

A potash source which has attracted unusual attention of late, is the kelp or giant sea weed that grows in considerable abundance along the Pacific coast from Lower California to Alaska. This plant has extracted potash from the sea water to such an extent that its ash contains 30 per cent. of this material. It would appear that if large areas of this weed could be harvested like a crop and efficiently treated, an effective industry would be the result. The plan has been put into more or less successful operation, at least in the areas of ranker growth in waters south of San Francisco, other products at the same time being saved; but the kelp industry, while it may be made permanent and important, can scarcely be expected to supply more than a very small part of our potash needs.

Perhaps the most significant outgrowth of the efforts toward potash development is the successful application of a method whereby a recovery is made of the dust escaping from the flues of Portland cement plants; this has become a commercial success at more than one locality and opens up the possibility, already under trial, of adding potash rocks or minerals to the normal raw products, so as to increase the by-product potash yield. A potash recovery from the waste dusts and gases from the iron blast furnaces is opening up also as a somewhat similar by-product possibility.

Sundry other sources, such as potash recovery from distillery wastes, wool washings, municipal wastes, ashes from sage brush, banana stalks, and beet-sugar wastes, need not be gone into in detail here, although many of them are producing in a small way. As further development along these lines is in keeping with the assumed principle that the productive utilization of waste products makes for the best interests of the Nation, the furtherance of these by-product activities assumes an importance out of proportion to the actual tonnage of production.

We have finally to examine the possibilities of those leaner but widespread sources of potash, upon which the world must fall back after the exhaustion of richer deposits. Four natural products stand forward in this connection: Feldspar, occurring in scattered and rather small deposits in many parts of the country; leucite, forming a conspicuous component of a rock mass of

¹A minor use of coal is for the manufacture of illuminating gas, but nitrogen is recovered from a relatively low percentage of coal used for that purpose.

²About a third of this ammonia is used in refrigeration, some 10 per cent in the manufacture of explosives and chemicals, while half or more goes into fertilizers in the form of ammonium sulphate.

mountain dimensions in Wyoming; sericite, in extensive beds in Georgia; and greensand, found widespread in the Atlantic Coastal Plain, especially in New Jersey. In each type the potash content is bound up in a very stable form of combination, thus demanding considerable chemical energy for its extraction. Many processes are quite feasible from a laboratory standpoint, but none has met with large-scale commercial success as yet. One of the most promising attempts, already locally successful, makes use of greensand or feldspar, and after the extraction of potash mixes the residue with sand to produce a good grade of brick. This process is not only ingenious in itself, but also illustrates that a raw product should not be looked upon as a mixture of value and waste, but as a combination of useful materials. It therefore serves once more to emphasize the importance of the by-product idea in our industrial development.

The outstanding feature of the potash situation is that the war has brought into existence a varied, loosely connected, and unstable domestic potash industry. What is to become of this industry with the resumption of peace? It will then have to meet the competition of the German potash deposits, which because of their size and workability can deliver potash to any part of the world more cheaply, generally speaking, than can any other source, however near. If it be decided that the American industry, born of war prices, should be stimulated into continued life, looking toward the gradual and normal establishment of American independence in regard to potash as a desirable eventuality, it will be necessary that the Government adopt a definite policy toward this end. Admitted that domestic competition with German potash is economically impossible on equal terms, there would appear to be two methods of making the balance even—either by putting a tariff on the imports from Germany, or else by subsidizing the domestic industrial enterprises to an appropriate degree. The first method would raise the cost of fertilizers to both the manufacturer and the farmer, and would meet with popular disfavor, if properly understood. The cost, in fact, would be too great and fall in the wrong place. The second method could be followed at a moderate cost to the Government; the expense would be distributed and therefore strike no particular class; and the price of food would not thereby be raised. The question would seem to resolve itself, in short, into whether eventual potash independence is worth the price of present governmental subsidy.

Bohr's Atomic Hypothesis

Bohr's latest formulation [Sci. Abs. 1437 (1915)] of his fundamental hypothesis is: "A. An atomic system possesses a number of states in which no emission of energy radiation takes place, even if the particles are in motion, and such an emission is to be expected in ordinary electrodynamics. The states are denoted as the states of stationary motion of the system under consideration." Liénard's well-known expression for the irreversible radiation from an electron is essentially positive, and it vanishes only with the acceleration; and the latter cannot vanish in the case of an electron moving in any way inside an atom. A is therefore necessarily inconsistent with Liénard's expression, which presupposes only the usual expressions for the retarded scalar and vector potential together with the Poynting energy flux. Now the author has shown elsewhere [Electromagnetic Radiation Ch. XI and App. C, D, and F] that the accepted equations of motion of the electron are a direct consequence of the classical equations of the electromagnetic field, Lorentz's and Larmor's expression for the mechanical force on a moving charge, and the definition of force and mass given by Newton's first and second laws of motion. Further, the energy equation derived from these equations of motion defines the kinetic energy of the electron and its radiation without any assumptions as to the proper expressions for the energy densities of the surrounding field and the energy flux. The reaction due to radiation is thus found to consume work irreversibly as well as reversibly, and the rate of the former is as given by Liénard's expression, which is thus shown independently to be consistent with the accepted electron mechanics, and the same holds good for the Poynting flux. The only way to retain A would therefore be if there could be found some modification of the accepted equations of the electromagnetic field which would annul the radiation derived from the Poynting energy flux. To change the Maxwell-Hertz equations for the distant field would apparently involve the loss of the accepted theory of electromagnetic waves. But the retarded potentials depend also on the form of the equations within the electron. A detailed analysis shows definitely, however, that no such modification is possible, allowing of the retention of the accepted elec-

tromagnetic equations at a distance from the electron together with the Poynting energy flux, in the case of electrons moving in coaxial circles. In the case of non-circular paths there is generally a tangential as well as a normal acceleration, so there is every reason to suppose that the radiation would be increased, and the author has little doubt that a formal proof could be given, but the already complicated calculations would be much more formidable. The author therefore suggests the modification of Bohr's hypothesis A into a form not open to these objections and which at the same time satisfies the requirements of Bohr's theory in all essential respects: "A. An atomic system possesses a number of states in which its electromagnetic energy continues unchanged even if the particles are in motion and an emission of energy radiation is to be expected in ordinary electrodynamics. The states are denoted as the states of stationary motion of the system under consideration." Stress is here laid on the constancy of the electromagnetic energy in spite of radiation, instead of on the total absence of emission of energy radiation. Such emission, as a consequence of radiation, is supposed to occur, not in quanta, but continuously. This need not, however, be inconsistent with Bohr's quantum hypothesis for the series spectrum emission in his hypothesis B. For, whenever emission in quanta occurs, it is now usually attributed to some cause arising from the constitution of the atom rather than that of radiant energy itself. And we have sufficient reason for supposing that the emission of spectrum series is a process of a very special kind, to which the quantum hypothesis may perhaps be applicable, while not holding for the ordinary emission of energy radiation accompanying all accelerated motions of electric charges.—Note in Science Abstracts on a paper by G. A. Schott in Phil. Mag.

How Flowers Were Named

A GREAT number of flowers have been named from their appearance, and many, too, from their properties. The daisy is (as Chaucer has it) "the eye of day"—i. e., the sun; the sun-flower is named from its rays of sunshine, yellow. There is also the moon-daisy; and from their fancied resemblance to a star we have such names as star-wort and star of Bethlehem. The geranium is the crane's-bill, the Greek word for a crane being *geranos*; and there are the crow-foot, snowdrop, auricle (or "little ear"), monkshood, foxglove (more correctly, folks' glove—the allusion being to the fairy-folk), the larkspur, the mulmool or monkey-flower; and, from their likeness to bell or cup, such names as harebell (not hair-bell), blue-bell, and buttercup. Some of these are named from the shape of the seed-case, as also are shepherd's purse and shepherd's needle.

From the form of the leaf we have bugloss (*bous glossa* in Greek, ox-tongue in English), dandelion (French, *dent-de-lion*, lion's tooth), hawk-bit, and colt's foot. The pimpernel, a corrupt form of "biplnel" (Latin, *bis* and *penna*), is the double-winged flower; periwinkle (Lat., *vincere*, to bind) is named for the same reason as the woodbine; the columbine bears some resemblance to the dove (*columba*). There are also the orchid and fumitory, the latter (*fume de terre*) said to be named from its abundance and perhaps its curly appearance.

From their properties, mostly medicinal, are named feverfew (i. e., febrifuge), comfrey (Lat., *con-feruere*), narcissus (narcotic), eye-bright (an eye-wash—"purging the visual nerve," according to Milton), wolf's-bane, flea-bane, hen-bane, nasturtium (nose twister), borage (from the Arabic, "father of sweat," a sudorific), honeysuckle, and lavender (used to scent linen fresh from the laundry).

Color gives their distinctive name to some, such as burnet (a brown flower), gowan or "gowlan" (a Norse word, the yellow flower), lilac (Arabic, blue), cowslip, dusty miller, and silver-weed.

A few are named from places or habitat, as candle-tuft (Candia), London pride, Canterbury bell, anemone (from growing in places exposed to the wind), and wallflower (from growing on ruined walls). Cinquefoil, trefoil, milfoil (or yarrow), are named from the number of their leaves. A few have poetical names—forget-me-not, pansy (think of me), and speedwell.

Religion, or devotion to the Virgin Mary, has suggested marigold, rosemary (an adaptation), lady'smock, lady's bedstraw, and lady's fingers.

Lobelia, fuchsia, and camellia are named from botanists of the sixteenth century.—J. L. R., in the Scotsman.

Prentice Pillars

In Folk-lore (vol. xxix, No. 3, September, 1918) Dr. W. Crooke discusses the tales of the prentice pillars and the architect and his pupil. We have in this country instances of such pillars at Roslin Abbey and Mel-

rose, and windows in Rouen Cathedral, where the story is current that the master, through envy, is said to have killed his pupil who constructed the work. In a second form of the tale the builder or architect is said to have fallen a victim to the jealousy of his employer, who feared that he might lose his reputation if the workman transferred his services to another master. Of this type of story numerous instances are quoted from India and other parts of the East. It has been suggested by Mr. H. A. Rose that the legend is based on the idea of a foundation sacrifice, the most appropriate victim being the person responsible for the work. But this does not easily explain some forms of the story, and further examples must be collected before the problem can be finally solved.—Nature.

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